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BACTERIOLOGY OF ACUTE INFECTIONS OF THE MIDDLE EAR AND MASTOID

JOHN RANDOLPH PAGE, M.D.
NEW YORK

Through the Manhattan Eye, Ear and Throat Hospital, I collected some data on the bacteriology of acute infections of the middle ear and mastoid from 300 cases referred for myringotomy from the clinics of Dr. Duel, Dr. Fowler and Dr. Haskin and from my own clinic. As these findings differ from those heretofore reported by others, I feel that a description of how they were obtained is called for.

METHOD OF STUDY

Only cases of acute infection of the middle ear in which myringotomy was indicated are included in this series. The duration of the infection in the whole group varied from a few hours to three weeks, the average being seven days. The age of the patients varied from 3 months to 63 years, the average age being 17 years. At the time of the myringotomy the rectal temperature varied from normal to 104 F. with an average of 101.2 F. Of the 300 cases, 231 presented unperforated ear drums, and 69 discharging ears. In the 231 cases in which there was no discharge from the ear there was an average duration of infection of five days and an average rectal temperature of 101.2 F. In the 69 cases in which there was a discharge, the average duration of the infection was eight days and the average rectal temperature, 100.6 F.

Five cultures were taken in each case on a divided blood plate containing a special medium of brain, veal agar and brain-heart infusion broth with normal blood, not citrated, and the same technic was followed throughout the series. Small applicators were used to avoid contamination from the walls of the canal. In the cases in which there was no discharge, the first cultures were taken from the drum membrane through a sterilized speculum. The second culture was taken after an antiseptic solution had been used in the canal. The third was taken from the knife after it had penetrated the membrane. The fourth was taken from a small swab that was immediately placed against the incision. The fifth was taken from the eustachian tube with a wire loop passed through a eustachian catheter. In the cases in which there was a

From the address of the president at the Annual Meeting of the American Otological Society, Atlantic City, N. J., April 6, 1934.

discharge, the same procedure was followed, except that after the first culture was obtained the canal was cleansed with hydrogen dioxide followed by an antiseptic solution. After some experiments with antiseptics in the canals in the first 100 cases, a 95 per cent solution of alcohol was found to be the most effective. The canal and concha were filled with it for from two to three minutes, except in the cases in which the ear drums had perforated, and it was then wiped out with sterile cotton. Nitrous oxide-oxygen anesthesia was administered in all of the cases except those in which the patient was less than 6 years of age.

RESULTS

In 223 cases cultures were taken from the eustachian tube; 188 showed growths of bacteria, and 35 were sterile. In 113 cases, the cultures taken from the tube and that obtained at myringotomy were the same.

In the group in which there was no discharge from the ear, cultures were taken from the eustachian tube in 170 cases. Twenty-six of these showed the pneumococcus type III. Nineteen of the twenty-six cases showed the pneumococcus type III in both the cultures taken from the knife and those taken from the eustachian tube. In 4 cases the cultures taken from the eustachian tube showed the organism while those taken from the knife showed no growth, and in 3 the reverse was found.

Ninety-two of the 300 infections, or 30.6 per cent, were due to the hemolytic streptococcus, and 51, or 17 per cent, to the pneumococcus type III. The table shows the types of infection in the two groups and gives the percentage of frequency of each in the group as a whole. I cannot explain the large number of sterile cultures from the eustachian tube, 80 in all. Those taken from the knife may have been due to the antiseptic solution that remained in the canal, and the 2 sterile cultures taken from the mastoid may have been due to the drying of the swabs before they were planted. One hundred and seventy-one patients, including 18 who were operated on for mastoiditis, were followed to recovery. The infections of 51 of these were due to the hemolytic streptococcus; 9, or 17.6 per cent, of these patients had operations on the mastoid, and 42 recovered without operation.

In the group with infections due to the pneumococcus type III, 35 patients were followed. Twenty-nine recovered without operation, and 6, or 17.1 per cent, had operations on the mastoid.

None of the patients who were operated on showed marked complications. Uneventful recovery occurred in all. No case of meningitis or death occurred in any of the 171 patients who were followed, or in the 300 so far as is known. In 1 case, that of bilateral mastoiditis due to the hemolytic streptococcus, a septic temperature developed after opera-

tion. Hemolytic streptococci were found in the blood stream, but recovery was prompt after one blood transfusion without further operation. As far as is known, mastoidectomy was performed in 18, or 6 per cent, of this series of 300 cases. It is of some interest to note that there were 2 patients with infection due to Friedländer's bacillus group who recovered in a short time without operation on the mastoid.

The possibility that the type VIII pneumococcus may have been included in the type III group in this series was suggested by Mr. Burchall of the New York Eye and Ear Infirmary. I am assured that with the characteristic mucoid growth of the type III pneumococcus on blood plates and the specific agglutination tests which were carried

Report of Cultures Taken at Myringotomy in 300 Cases of Acute Infection of the Middle Ear *

Types of Organisms	No. of Cases	Per Cent	Discharging Ears (69 Cases)				Nondischarging Ears (231 Cases)			
			Knife	Tube	Cured	Mastoidectomy	Knife	Tube	Cured	Mastoidectomy
Str. haemolyticus	92	30.6	31	19	11	5	61	42	31	4
Pneumococcus type III	51	17.0	12	7	5	2	39	26	24	4
Staph. aureus	38	12.7	6	3	5	..	32	16	15	..
Staph. haemolyticus	16	5.3	7	3	3	..	9	4	6	..
Staph. albus	15	5.0	5	2	3	1	10	5	2	..
Staph albus and aureus	8	3.0	2	2	..	..	6	2	4	..
Str. viridans	4	1.5	1	..	1	..	3	2	2	..
Pneumococcus type IV	2	0.7	..	..	..	..	2	2	1	..
B. coli-communis	2	0.7	..	..	..	..	2	2	..	..
Friedländer's bacillus	2	0.7	..	..	..	..	2	2	2	..
Str. haemolyt. and Staph. aureus	2	0.7	..	..	1	..	2	2	..	..
Hemolytic staph. and B. coli	1	0.32	..	..	..	..	1	1	1	..
Str. gamma	1	0.32	..	..	..	..	1	1	..	..
No growth	66	22.0	2	17	..	..	64	63	36	2
Not taken	..	....	..	16	..	..	..	61	..	..

* Average age, 17 years; average temperature, 101.2 F.; average duration of infection, 7 days.

out on the entire series, confusion of the two types was unlikely. This assurance comes to me from Dr. Eggston, and from Dr. Goodner and Dr. Francis of the Rockefeller Institute through Mr. Berg and Dr. Davis, who, at my request, consulted them on this question. The last half of this series was, nevertheless, examined especially for type VIII pneumococci with agglutinating serum supplied by Dr. Goodner, but none was found.

Dr. Eggston stated that a review of the bacteriologic records of the Manhattan Eye, Ear and Throat Hospital for a period of five years, from 1920 to 1925, reveals 2,303 streptococcic cultures in acute infection, hemolytic streptococcus being recovered in 928, the nonhemolytic streptococcus in 1,296 and the pneumococcus type III in only 61, less than 0.5 per cent of the whole series as compared with 17 per cent reported here. He offers as an explanation the possibility that the cultures were not as carefully taken or as carefully typed then as now.

Dr. Marvin Jones found that 221 of 252 cases of mastoiditis were due to the hemolytic streptococcus and 20 to the pneumococcus group, of which 6 were type III, 1 type IV, 1 type VIII and 1 type VI. The other 11 were untyped.

Dean [1] stated that in every case of his series in which the type III pneumococcus was found at myringotomy, operation on the mastoid was necessary sooner or later. In my series of 51 patients with infections due to the pneumococcus type III, 29 or over 82 per cent, of the 35 who were followed, recovered without the necessity for an operation on the mastoid.

Hadjopoulos [2] found pneumococci in 5 of his series of 91 cases, type III in 4 instances and type I in 1. Three of 4 patients with infections due to the pneumococcus type III died of abscess of the brain. Hadjopoulos said, "It is fortunate that the incidence of this group is very low."

In the series of 300 patients, 51, or 17 per cent, had infections due to the pneumococcus type III; 35 were followed, and 29 recovered without operation on the mastoid.

While in this series the pneumococcus type III was not as universally destructive as some have found it to be, it occurred more frequently in the middle ear than any other organism, except the hemolytic streptococcus, and it warrants more than any other organism a guarded prognosis because of its insidious and virulent character, although in this series operation on the mastoid was necessary in a slightly lower percentage of the cases in which it was found than in those due to the hemolytic streptococcus. These findings emphasize the fact that involvement of the mastoid does not depend solely on the virulence of the infection but on the patient's resistance to it as well, and on the anatomy of the particular mastoid involved, which may tend to retain or expel the infection. Operation, therefore, is not warranted because the organism has a bad reputation, when clinical signs point to recovery in spite of it. On the other hand, it is well to emphasize again, although it is generally recognized, the insidious character of the pneumococcus type III, which calls for experienced judgment and watchful attention to the signs in the fundus of the ear rather than elsewhere, in order to determine when operation is necessary. Too early operation on a "green mastoid" is as much to be avoided as delay until the inner plate has softened.

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1. Dean, L. W.: Cytological and Bacteriological Studies, Tr. Am. Otol. Soc. **22**:39, 1932.

2. Hadjopoulos: Bacteriologic Differentiation and Specific Etiology of Mastoiditis, Ann. Otol., Rhin. & Laryng. **39**:1017 (Dec.) 1930.

In this series some light is thrown on the relative advisability of early and delayed myringotomy in cases of acute infection of the middle ear. Eighteen mastoidectomies were performed in the 171 cases that were followed to recovery. Operation on the mastoid was performed in 8, or 21.6 per cent, of the 37 cases in which the ear drums ruptured before myringotomy and in 10, or 7.4 per cent, of the 134 cases in which myringtomy was performed before rupture occurred. Almost three times as many operations on the mastoid were necessary in the cases in which the drums ruptured spontaneously as in those in which myringotomy was performed before rupture occurred.

BACTEREMIA AND ACUTE INFECTIONS OF THE UPPER RESPIRATORY TRACT

HOWARD C. BALLENGER, M.D.
CHICAGO

Acute infections of the upper respiratory tract are usually ushered in by the common cold. Many different organisms have been suspected to be the causative agent. The known pathogenic bacteria that are found in the nose and throat at most times are the various streptococci, pneumococci, staphylococci, certain gram-negative cocci and Pfeiffer's bacillus [1] or, as it is known today, Haemophilus influenzae.

The possibility that a filtrable virus is the cause of the common cold was first suggested by Kruse [2] in 1914. He reported the experimental production of colds by means of a bacteria-free filtrate. Foster [3] obtained similar results. However, many other observers have failed to confirm Kruse's findings. Dochez and his associates [4] reported the experimental transmission of the common cold to anthropoid apes and human beings by means of a filtrable agent. Their work on chimpanzees is suggestive experimental evidence that the etiologic agent of the common cold is able to activate pathogenic bacteria usually present in the upper respiratory tract, such as the streptococci and pneumococci. Further studies by this group [5] showed that the virus "survives anaerobically in the cold for at least 13 days; it is inactivated at comparatively low temperatures by heat and lastly it has been demonstrated to multiply in tissue culture medium of the type previously employed in cultivation of vaccine virus."

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1. Pfeiffer, R.: Vorläufige Mitteilungen über die Erreger der Influenza, Deutsche med. Wchnschr. **18**:28, 1892.

2. Kruse, W.: Die Erreger von Husten und Schnupfen, München. med. Wchnschr. **61**:1547, 1914.

3. Foster, G. B., Jr.: The Etiology of Common Colds, J. A. M. A. **66**:1180 (April 15) 1916.

4. Dochez, A. R.; Shibley, G. S., and Mills, K. C.: A Study of Acute Infections of the Respiratory Tract in the Ape, Proc. Soc. Exper. Biol. & Med. **26**:562 (April) 1929; Experimental Transmission of the Common Cold to Anthropoid Apes and Human Beings by Means of a Filterable Agent, J. Exper. Med. **52**:701 (Nov.) 1930.

5. Dochez, A. R.; Mills, K. C., and Kneeland, Y., Jr.: Diseases of the Upper Respiratory Tract: Problems Connected with the Etiology and Prophylaxis, J. A. M. A. **101**:1441 (Nov. 4) 1933.

The evidence that influenza is caused by a filtrable virus is not so clear. Shope [6] found that a filtrable virus was the essential factor in influenza of swine. The virus alone produced a very mild disease. Haemophilus influenzae (suis) alone gave no evidence of an infection, but when combined with the virus, the swine type of influenza resulted. Smith and his co-workers [7] reported a disease of ferrets following an intranasal instillation of filtrates of washings from the throats of patients with influenza. The disease could be transmitted by contact from the infected ferrets to other ferrets. The nasal secretions from the common cold did not cause the disease, nor did washings from the throats of healthy persons or from persons convalescing from influenza.

This apparent symbiosis of a filtrable virus with the known pathogenic bacteria of the nose and throat would explain the frequently seen clinical phenomenon of an initial mild rhinitis or pharyngitis later developing into a severe infection of the respiratory tract of the streptococcic or pneumococcic type.

The fact is well known that in recent years from 80 to 90 per cent of all cases of mastoiditis and probably other complications of acute infections of the throat are due to the hemolytic streptococcus. Soper and Dynes,[8] in a review of 250 cases of mastoiditis seen at the Evanston Hospital from Jan. 1, 1927 to June 1, 1933, found that 84 per cent were due to the hemolytic streptococcus. Kopetzky and Hadjopoulos [9] reported the hemolytic streptococcus as the causative agent in 90 per cent of their cases. It is with this organism that otolaryngologists are primarily concerned. In 1926, I [10] reviewed the recent literature concerning this organism, particularly in regard to a possible bacteremia from acute infections of the throat. As a result, the classification and bacteriology will not be entered into at this time.

There are various ways by which the hemolytic streptococcus may be spread to other portions of the body from the nose and throat, such as:

1. Direct extension by continuity of tissue. This is best exemplified by mastoiditis and sinusitis.

2. Extension by way of the lymphatics, with resultant cervical adenitis and retropharyngeal abscess.

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6. Shope, R. E.: Swine Influenza, J. Exper. Med. **54**:349 (Sept.) 1931.

7. Smith, W.; Andrews, C. H., and Laidlaw, P. P.: Virus Obtained from Influenza Patients, Lancet **2**:66 (July 8) 1933.

8. Soper, G., and Dynes, J.: Tr. Evanston Hosp. Staff Meet., November, 1933.

9. Kopetzky, S. J., and Hadjopoulos, L. G.: Relationship of Upper Respiratory and Alimentary Infections to Mastoid Infections, Laryngoscope **42**:661 (Sept.) 1932.

10. Ballenger, H. C.: Bacteremia and Acute Hemolytic Streptococcic Throat Infections, Arch. Otolaryng. **4**:97 (Aug.) 1926.

3. Infection through the alimentary tract. However, this means of transmission is not so important as might be supposed as the gastric and intestinal secretions destroy the hemolytic streptococci very rapidly. Davis [11] found the organisms dead in from three to five minutes when placed in the stomachs of rabbits.

4. Bacteremia, or a blood-borne infection from the upper respiratory tract. In recent years this complication has received an ever-increasing recognition. I believe that a transitory or an evanescent type of bacteremia is fairly common and occurs much more frequently than is popularly supposed. This bacteremia, as a rule, does not produce distant foci of infection or discernible involvement of other organs as is implied in the older term of "septicemia."

Kellogg and Hertig [12] reported a severe epidemic of puerperal sepsis in a Boston hospital during the "respiratory season" of 1911, which they considered to be primarily throat-borne. They also reported a similar epidemic of puerperal sepsis in 1931 in a well equipped general hospital with a small maternity wing in which there were 10 women who had been delivered. Two of the women died. Cultures of the blood stream and of the uterine cavity revealed hemolytic streptococci. No report was made of cultures of the throat.

The cutaneous eruptions, particularly over the chest or extremities, that frequently accompany grip or influenza are familiar to all. This dermatosis may take the form of a roseola or of a rash of the roseolopetechial, roseolovesicular, scarlatinal, morbilliform, papular, urticarial or eczematous type. Possibly other forms have been observed. The great majority of the eruptions are of the roseolic type. In an effort to determine the pathogenesis and a possible relationship to a bacteremia as the causal factor, I reviewed the literature from 1912 to the present. There could be much discussion in regard to the relative rôles played by toxins, anaphylaxis, bacteria or a filtrable virus as the cause. Possibly all of the foregoing agents are factors at different times. Nothing was found which proved that a bacterium or a virus was the cause. At the same time, nothing was found which proved that a bacterium or a virus was not the cause, with the possible exception of the allergic types. Lortat-Jacob and Solente,[13] in a review of the literature in 1930, expressed doubt as to the infectious origin of the dermatosis. Rosen-

11. Davis, D. J.: Hemolytic Streptococci with Special Reference to Their Rôle in Acute Respiratory Infections, J. A. M. A. **72**:319 (Feb. 1) 1919.

12. Kellogg, F. S., and Hertig, A. T.: The Relationship Between Exogenous Throat Streptococci and Puerperal Infection, Am. J. Obst. & Gynec. **25**:213 (Feb.) 1933.

13. Lortat-Jacob, A., and Solente: Cutaneous Eruptions and Lesions in Grippe, Presse méd. **38**:1025 (July 30) 1930.

baum [14] reported 5 cases of infants with grip accompanied by morbilliform eruptions, which were most intensive over the extremities. Four of these infants died from sepsis. Necropsies gave practically no pathologic information in regard to the dermatosis. In 4 of the 5 deaths the agent causing the sepsis was the hemolytic streptococcus.

Reith and Squier,[15] in 1932, cultured the blood of 293 apparently healthy people. Positive blood cultures were obtained in 12 per cent of 99 persons without evident foci of infection, and in 27 per cent of 194 persons with chronic foci of infection. Of 24 persons with pains in the joints or muscles or with chronic arthritis, 10, or 42 per cent, gave positive blood cultures for the streptococcus or diplococcus. The interesting part of this investigation was the marked increase of the positive blood cultures obtained during the winter months when infections of the upper respiratory tract are prevalent. In the group without demonstrable foci of infection, the increase was from a low of 6 per cent during the summer to a high of 17 per cent in the fall and early winter.

The bacteremia, if present, is difficult to demonstrate by the usual means of blood culture. The difficulties encountered may be:

1. The bacteria are not present in the quantity of blood withdrawn.

2. The showers of bacteria may not be present in the blood at the time the cultures are taken.

3. Improper technic, the wrong culture medium or too short a period of cultivation may be the cause of failure.

4. The filtration system of the blood stream, that is, the liver, spleen, lungs and finer capillaries or the phagocytic cells, particularly of the reticulo-endothelial system, may remove most or all of the bacteria before they reach the vein of the arm or neck from which cultures are usually taken. Cannon and his associates [16] have shown that the liver and spleen remove enormous numbers of bacteria injected into the blood stream of animals. It is generally agreed by most workers that following the injection of bacteria into the blood stream of animals practically all bacteria, regardless of virulence, are primarily removed from the blood stream within a few hours.

5. Recent studies in pleomorphism and transmutation or dissociation of bacteria may explain the lack of positive blood cultures in many instances. If this is true, recognized strains may be in a filterable phase

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14. Rosenbaum, S.: Ueber morbilliforme Neugeborenengrippe mit septischem Ausgang, Monatschr. f. Kinderh. **43**:153, 1929.

15. Reith, A. F., and Squier, T. L.: Blood Culture of Healthy Persons, J. Infect. Dis. **51**:336 (Sept.-Oct.) 1932.

16. Cannon, R. P.; Sullivan, F. L., and Neckermann, E. F.: Disappearance of Bacteria from the Blood Stream, J. Exper. Med. **55**:121 (Jan.) 1932.

or may react in an unusual or inconstant way to the usual staining or cultural methods.[17]

In an effort to determine how frequently this apparent bacteremia could be demonstrated, Dr. Rubin, Miss Werner and I,[18] at the Children's Memorial Hospital in Chicago in 1930, made 131 blood cultures from 63 children with various stages of acute or subacute infections of the throat. A positive blood culture was obtained in about 6 per cent of the cases. If cultures had been taken from an artery, such as the carotid, the percentages of positive cultures probably would have been much greater. Ottenberg described such a method.

I recently reported before the Chicago Laryngological and Otological Society [19] a striking example of an overwhelming bacteremia from an acute infection of the throat. In this case, G. S., a boy, 8 years of age, had a slightly inflamed throat, cervical adenitis and a reddened ear drum, with a moderate febrile reaction. Death occurred in about ten days. Autopsy revealed a marked bacteremia with numerous small abscesses throughout the body, especially in the lungs and brain. Even the eyeballs had numerous small abscesses. No portal of entrance of the infection into the blood stream other than the throat could be determined.

The increased incidence of appendicitis following epidemics of sore throat is familiar to all. As pointed out in a former paper,[10] in many of these cases it has been proved that the infection was transmitted from the throat to the lymphoid tissue of the appendix by way of the blood stream. This is also true in cases in which the peritoneum is infected. In the peritoneal cases the hemolytic streptococci have been recovered from the throat, the peritoneum and the blood stream and there has been no evidence of an intraperitoneal lesion. Such cases have been reported by Künzel,[20] Chapelle,[21] Greenebaum and Ransohoff,[22] MacLennan and McNee [23] and others. There is no doubt that an epidemic of acute peritonitis as well as acute appendicitis may be secondary to an epidemic of acute infections of the throat and transmitted by way of

17. Traut, E. F.: Blood Cultures in Chronic Arthritis, J. Infect. Dis. **52**:230 (March-April) 1933.

18. Ballenger, H. C.; Rubin, M. I., and Werner, M.: Bacteremia and Acute Throat Infections, J. A. M. A. **95**:1828 (Dec. 13) 1930.

19. Ballenger, H. C.: Brain Abscess with Attempted Orbital Drainage, Arch. Otolaryng. **17**:730 (May) 1933.

20. Künzel: Eitrige Peritonitis im Anschlusse an akute Tonsillitis, München. med. Wchnschr. **51**:1920, 1904.

21. Chapelle: Arb. a. d. path. Inst. zu Helsingfors **2**:583, 1907.

22. Greenebaum, J. V., and Ransohoff, J. L.: Acute Appendicitis and Pneumonia in a Baby Fourteen Months of Age, Am. J. Dis. Child. **28**:76 (July) 1924.

23. MacLennan, A., and McNee, J. W.: Primary Streptococcal Peritonitis in a Child with Septicemia Ending in Recovery, Brit. J. Dis. Child. **10**:258, 1913.

the blood stream. Chapelle [21] reported such an epidemic in children during an epidemic of sore throat. He recovered the organism from the throat, the blood stream and the peritoneum.

Many acute infections of the kidney, heart, brain and other organs or structures of the body occurring during acute infections of the upper respiratory tract can be explained only by transmission of the infection by way of the blood stream.

Admitting that a large majority of acute infections of the throat are due to the hemolytic streptococcus, and also that a bacteremia from these infections is a possibility or even a probability, what deductions can be made?

1. With this apparent tendency of the hemolytic streptococci to invade the blood stream or to extend to the nearby regions during the acute stage of the infection, it is obvious that operations on the throat and nose should be deferred until a quiescent period has been reached. Many operations have been made and can be made on the various structures in the nose and throat during the acute stage of an infection without trouble other than a stormier convalescence than they would otherwise have had. However, if a sufficient number are done, the percentage of complications in the nearby structures or in the remote regions of the body will be increased. Bleeding from a throat four or five days after tonsillectomy is frequently from this cause. Tillett and Garner [24] have shown that hemolytic streptococci of human origin possess the ability to liquefy or dissolve human fibrin within a short time. This property was found in 28 strains of the hemolytic streptococcus. In most cases this lysis was complete within fifteen minutes. Most of the nonhuman strains of the hemolytic streptococcus did not possess this lytic property, nor did a large number of other bacterial species tested. This property may explain the apparent ease with which the hemolytic streptococcus invades tissue, including the blood vessels. Other unsatisfactory results following a tonsillectomy during an acute infection of the throat due to hemolytic streptococci may be sinusitis, otitis media, various pulmonary and thoracic conditions, adenitis and cellulitis. Undoubtedly, the blood stream would be more easily invaded during the acute stages of these infections than during a later and quiescent period.

2. With an extension of the infection of the throat to the middle ear, the question would arise whether the tympanic membrane should be incised as soon as bulging is detected. I believe that this should be done as the risks of a further involvement of the structure of the ear seem to be less if the ear drum is opened as soon as the bulging occurs

24. Tillett, W. S., and Garner, R. L.: Fibrinolytic Activity of Hemolytic Streptococci, J. Exper. Med. **58**:485 (Oct.) 1933.

than if delay is practiced. However, on clinical grounds, I am led to believe that opening an ear drum, particularly during the stage of blisters on the tympanic membrane that one frequently sees in an infection due to the hemolytic streptococcus, produces a temporary bacteremia. This would explain most easily the rather sudden increase in temperature that frequently takes place from twenty-four to forty-eight hours following an early incision. The bacteremia, if present, seems to have no apparent ill effect in the vast majority of cases. In the exceptional instance, it may, as in the following case, recently observed:

B. G.,[25] 8 years of age, had measles. One week later an earache developed. When I examined her, I found a red bulging ear drum with two or three serum-filled blisters. The ear drum was incised, and a free bloody discharge followed. The opposite ear drum was pink, but there was no displacement. That night about 11 o'clock I saw the patient again and found the second ear drum to be red and bulging, with blisters on the tympanic membrane. This drum was also incised, and a profuse bloody discharge followed. The patient did not improve, but steadily grew worse. Her temperature reached 105 F. each day, with but slight remissions. A profuse mucopurulent discharge from the nose was present throughout the illness. She complained of no pain and gradually grew semicomataose, but could be aroused. Evidence of meningeal involvement was absent. Death occurred on the eleventh day following the incision of the first ear drum. Autopsy revealed an overwhelming septicemia with multiple small abscesses throughout the body. There were pansinusitis and bilateral mastoiditis. The central nervous system was uninvolved. The entrance of the infection into the blood stream could not be determined. It is probable in this instance that the incisions of the ear drums combined with a virulent infection were sufficient to produce the infection of the blood stream. It is also possible that the entrance was obtained from the mucous membrane of the sinuses, the mastoid or the throat, although evidence of this could not be obtained.

3. If mastoiditis has developed and it is felt that a mastoid operation will have to be done ultimately, when is the best time to interfere? No set rule can be formulated as each case must be judged separately with a full knowledge of the anatomy, possible pathology and bacteriology of the temporal bone. If one can wait three weeks from the onset of the discharge with reasonable safety, I believe that it is desirable to do so. By that time the mastoid cells have become partly or completely decalcified. Nature has had a chance to throw up her protective barriers, thereby decreasing the possibility of further spread of the infection.

I recently saw a boy, B. L.,[25] 6 years of age, who had bilateral mastoiditis. From the clinical and roentgenologic aspect, both mastoids were involved in about the same degree of severity. I performed a simple mastoidectomy in one ear two and one half weeks after the onset

25. Ballenger, H. C.: Acute Upper Respiratory Tract Infections, J. Indiana M. A. **27**:207 (May) 1934.

of the condition and in the second ear, four weeks after. Healing in both ears was almost simultaneous. However, as has been said before, each case must be judged separately. If reasonable delay is possible, I believe that it should be exercised.

CONCLUSIONS

From clinical observation, from reports in the literature and from such bacteriologic investigations as have been done, I am led to believe that a transitory or an evanescent type of bacteremia is fairly common and possibly the usual complication following an acute infection of the upper respiratory tract, especially when due to the hemolytic streptococci.

Unexplained fever or fever out of proportion to the degree of the involvement of the throat can be explained by this probable bacteremia.

If this bacteremia is present, possible complications are limited only by the distribution of the blood stream.

VICARIOUS VOCAL MECHANISMS

THE ANATOMY, PHYSIOLOGY AND DEVELOPMENT OF SPEECH IN LARYNGECTOMIZED PERSONS

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With the improvement of surgical technic in total extirpation of the larynx has gone an increasing interest in methods of restoring voice to larynxless persons. Operative methods have made by far the greater progress. Perhaps the surgical laryngologist has considered it more important to eliminate satisfactorily a diseased organ than to restore the function which the organ discharged. Whatever the reason for the minor interest in functional recovery, the patient whose larynx was removed, deprived of speech, found himself restored to health which was well nigh identical with social helplessness.

The chief step toward the mitigation of this serious handicap was the invention of the artificial larynx. For many years laryngectomized persons have been carrying about these cumbersome and difficult machines. Only comparatively recently has attention been turned to the development in the patient of a vicarious voice by the use of organs other than the larynx. This has been accomplished with considerable success.

HISTORY AND CHRONOLOGY

To consider the record for a moment. In 1859, Czermák,[1] while studying a case of complete laryngeal stenosis, conceived the idea that the expiratory current of air issuing from the tracheal cannula which the patient carried could be used to produce voice and speech if it were conducted into the mouth through a tube containing a reed capable of vibrating. Brucke [2] embodied the idea in an apparatus. The patient using it could, with sufficient pains, produce single syllables. A few years later, Czerny,[3] experimenting with animals, contrived several dif-

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1. Czermák, J.: Ueber die Sprache bei luftdichter Verschliessung des Kehlkopfs, Sitzungsb. d. k. Akad. d. Wissensch. Math.-naturw. Cl., Wien **35**:65, 1859.
2. Brucke, cited by Czermák.[1]
3. Czerny: Versuche der Kehlkopfsexstirpation an Hunden, Wien. med. Wchnschr. **20**:557 and 591, 1870.

ferent machines. Billroth,[4] who, in 1873 performed the first successful total extirpation of the larynx, following Czerny's lead, worked out, with Eiselberg, a laryngeal prosthesis in which the tone was conducted through the tracheal opening into the pharyngeal cavity. This artificial larynx consisted of three parts—a tracheal, a pharyngeal and a phonation cannula. The phonation cannula was set inside the pharyngeal cannula. The tone-producing reed which was thrown into vibration by the expiratory breath was set in the phonation cannula. The tone, when projected into the resonating space above, could be transformed into sounds of articulate value.

In the course of a year this artificial larynx was further improved. Bruns,[5] endeavoring to make the artificial tone like the natural, discarded the rigid laryngeal tube and replaced it with a flexible semirubber membrane. Stoerk[6] employed an ordinary reed pipe placed between the teeth and connected with the tracheal cannula by means of a rubber tube through which the expiratory breath current went to the reed. The patient articulated at the same time that he produced the tone. If he wished, he could sound the reed by means of a double balloon bulb specially adapted for it. The purpose of other improvements, such as J. Wolff's,[7] was to prevent the accumulation of secretions and particles of food. The purpose of still others was to reduce irritation by the machine, cases of recurrence having been reported in which the irritation of tissue in contact with the apparatus was suspected as a contributing etiologic factor.

Gottstein,[8] with this in mind, took up the ideas of Czermák and Stoerk again. His apparatus had an accessory piece adapted for the trachea, being connected with a flexible rubber tube, the wall of which was held rigid by means of a spiral wire within it. To the free end of this rubber tube was attached a metal piece so placed as to lie behind the last molar tooth. Air from the trachea reached the pharyngeal cavity by this route. The voice-producing mechanism *per se* was placed in the rubber tube.

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4. Billroth, T., cited by Gussenbauer, C.: Ueber die erste durch Th. Billroth am Menschen ausgeführte Kehlkopfsexstirpation und die Anwendung eines künstlichen Kehlkopfes, Arch. f. klin. Chir. **17**:343, 1874.

5. Bruns, P.: Ueber einige Verbesserungen des künstlichen Kehlkopfes, Verhandl. d. deutsch. Gesellsch. f. Chir. 10 Kongr. **10**:51, 1881.

6. Stoerk, K.: Ueber Exstirpation des Larynx bei Karzinom, Arch. f. Laryng. **5**:22, 1896; Ueber Larynxexstirpation, Wien. med. Wchnschr. **37**:1535, 1887; Klinik der Krankheiten des Kehlkopfs, Stuttgart, Ferdinand Enke, 1880, p. 546.

7. Wolff, J.: Ueber den künstlichen Kehlkopf und die Pseudo-Stimme, Arch. f. klin. Chir. **45**:237, 1893; Berl. klin. Wchnschr. **30**:1009, 1893.

8. Gottstein, J.: Pseudo-Stimme nach Totalexstirpation des Larynx, Arch. f. klin. Chir. **62**:126, 1900.

Without any knowledge of Stoerk's apparatus, which has already been described, Hochenegg,[9] after a series of experiments, prepared an apparatus similar to it, but differing primarily in the manner of application. Thus, the artificial breath current for activation of the reed was conducted through the nose into the oropharynx, and its source, instead of being a small balloon, consisted of a bellows fastened to the left side of the patient's thorax. Hochenegg had to abandon his first idea of activating the reed by the pulmonic air itself. The patient was found to lack force of breath sufficient to initiate a tone, and, besides, the instrument made him cough violently. This was the state of affairs when Gluck[10] and his co-workers appeared. These physicians are intimately associated with an epochal period in the history of laryngeal surgery. They made fundamental modifications of the technic used in total extirpation of the larynx. They invented and constructed laryngeal prostheses ingenious enough to influence radically the patient's postoperative social status. Gluck constructed a whole series of cannulas and artificial larynges activated by bellows. His later models, however, were made to depend on the lungs for bellows, the vibrating mechanism being placed within an endonasal or endo-oral metal olive. He also prepared tiny voice boxes connected with bellows and compression chambers, which could be activated mechanically or electrically. These permitted the production of speech by means of a similar sensitive vocal olive. Later, he prepared gramophone records on which was registered a sustained tone beautifully sung by a good singer, which was capable of amplification by means of a diaphragm. This tone, conducted through a tube in the patient's mouth, could be articulated and used for the purpose of speech. Interruption of the tone was controlled by a special adjustment. Tests with this method showed much promise, but its further development seems to have met some obstacle. Perhaps the increasing evidence of the possibility of developing a vicarious voice physiologically influenced its abandonment. Whatever the cause, the general opinion now is that all these apparatus are unnecessary, except in cases in which the production of a vicarious voice for some reason proves absolutely impossible. This, however, is rarely the case.

The problem of producing an artificial voice varied with the technic of laryngectomy. As it is now performed, laryngectomy excludes any communication between the trachea and the pharynx. The present-day

9. Hochenegg, J.: Ein neuer Sprechapparat, Wien. klin. Wchnschr. **5**:123, 1892.

10. Gluck, T.: Der gegenwärtige Stand der Chirurgie des Kehlkopfs, Pharynx, Oesophagus und der Trachea, Monatschr. f. Ohrenh. **38**:89 and 141, 1904; Vortrag auf dem I. internat. laryngo-rhinol.-Kongr., Wien., 1908, 66; Das technische und funktionelle Problem bei den Operationen an den oberen Luft- und Speisewegen, Internat. Centralbl. f. Laryng. **29**:610, 1913; Probleme und Ziele der Chirurgie der oberen Luftwege, Monatschr. f. Ohrenh. **55**:1150, 1921.

devices are thus primarily conditioned by this fact. Some of the more recent laryngeal prostheses are remarkably skilful contrivances. Ónodi [11] constructed a model in which the tone is carried by means of a microphone into the nasopharynx. The devices of MacKenty,[12] Leyro Díaz,[13] Casadesus,[14] Tapia [15] and Hinojar [16] are based on the same fundamental idea, but naturally each author considered his own device the best. A detailed description of all these devices is given in the respective articles by these laryngologists.

DISADVANTAGES OF LARYNGEAL PROSTHESES

The disadvantages of the older laryngeal prostheses were many. Some of the devices were believed to irritate the tissue and to account for occasional cases of recurrence, as has already been mentioned. Many produced shrill and squeaky sounds. Others caused respiratory complications. All increased salivation unpleasantly. The business of speaking was rather painful and trying. Although later apparatus make things easier for the patient, their cost is, for many patients, prohibitive, and this is one obstacle to their widespread use. Even when the patient can afford one, it often fails to work through no fault of his own and causes him much anxiety and excitement.

The chief reason for not using even the best of these devices, however, is the fact that there is hardly a patient who, within a relatively short time, cannot be taught to cultivate a fairly loud voice capable of a certain degree of modulation. This, when articulated, becomes a speech more natural and "human," more clearly enunciated, even in cases in which the result is mediocre, than the best speech produced by mechanical means. Furthermore, for psychologic reasons, the mastery of vicarious voice is of great importance in maintaining the health of the laryngectomized person's psyche. A mechanical device can never have the same psychologic significance as a living organ with a newly developed function. Such a function becomes entirely identified with the personality. This is not likely when a mechanical device is used.

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11. Ónodi, A.: Ergebnisse der Abteilung für Hör-Sprach-Stimmstörungen und Tracheotomierte, Monatschr. f. Ohrenh. **52**:85, 1918.

12. MacKenty, J. E.: An Apparatus for the Laryngectomized, Ann. Otol., Rhin. & Laryng. **34**:1265, 1925.

13. Leyro Diaz, J.: Laryngectomy and the Artificial Larynx, Semana méd. **31**:27, 1924.

14. Casadesus: Phonetic Apparatus for Laryngectomized, An. Acad. méd. quir. españ. **10**:109, 1923.

15. Tapia, A. G.: Presentación de un laringuectomizado hablando con un sencillismo aparato artificial, Rev. españ. de laringol. **4**:49, 1914.

16. Hinojar, A.: Simple Phonetic Apparatus, Ann. Acad. méd. quir. españ. **10**:93, 1923.

EARLY CASES

Records of the early cases of so-called pharyngeal voice are sufficient to justify the inference that the phenomenon was not at all uncommon. Early mention is not infrequently made of cases in which voice developed without the intervention of respiratory function, although there had been complete occlusion of the larynx or total extirpation whereby communication between the trachea and its superposed parts had been completely obviated.

Here Czermák [1] was again a leader. He reported one of the first observed cases, that of a girl who had suffered from complete occlusion of the larynx below the glottis. This had entirely cut off the phonic function of respiration; yet a short time after the necessary tracheotomy she was able to produce speech. It occurred to Czermák that the use of the slight amount of air which might be contained in the pharyngeal and oral cavities, together with such sounds as might be caused during the movements of articulation by the cleavage of tenacious secretion from the mucous membrane with which it was in contact, might be the means of the production of speech. He gave particular attention to the formation of vowels and consonants, seeking to find out how they were produced. Stoerk [6] reported a case of a person who had been frustrated in the attempt to commit suicide by cutting his throat. In healing, a complete adhesion had formed between the cords. Yet the patient was able to talk comprehensibly. In a second case, reported by Stoerk and Gersuny, a fine voice and speech developed, although the larynx had been entirely extirpated because of carcinoma. Examination carried out as for laryngoscopy showed a slit in the transverse direction. It was there that the "voice" originated. The slit functioned like a glottis, its anterior lip being formed by the lower part of the nodus epiglottidis (the epiglottis had been left intact), while the flaps of mucous membrane which had been resected from the arytenoid cartilages and sewed together served as the posterior lip.

Poppert [17] observed a case of total laryngectomy in which there was remarkable clarity of whispered speech immediately following the operation and in which speech developed rapidly during convalescence. A case of development of fine voice and speech after total extirpation of the larynx because of suspected cancer was reported by Schmid,[18] who subsequently studied the case. His investigations resulted in two important observations: first, that the patient was able to speak for a fair

17. Poppert: Zur Frage der totalen Kehlkopfsexstirpation, Deutsche med. Wchnschr. **19**:833, 1893.

18. Schmid, H.: Zur Statistik der Totalexstirpation des Kehlkopfes im funktionellen Sinne, laute verständliche Sprache, Arch. f. klin. Chir. **38**:132, 1899.

length of time when the tracheal cannula was closed off, and, second, that speech was possible only when the mouth was completely empty—that is, the patient could not speak and eat at the same time. With the mouth open, the patient could produce the value "ah" in three different intensities from loud to soft, following each other quickly, provided that the effort was simultaneous with the opening of the mouth. If the patient started to make the sound even a small fraction of a second after opening his mouth, he failed. Try as he might, he could produce neither that nor any other sound, not even a belch.

This case was studied by Strübing and Landois [19] phonetically. They discovered that the air contained within a cavity caused by the operation was compressed by muscular contraction and thus vicariously took over the bellows function of the lungs. They believed that the muscles involved were the styloglossus, the stylohyoid, the keratoglossus and the chondropharyngeus. The slit formation above the air chamber mentioned served as a vicarious glottis and made possible a "stenotic noise." This, when articulated, effected a manner of speech. The air chamber, which was really the pharyngeal cavity, was emptied and refilled with air as the muscles which compressed it relaxed. Cohen [20] and Seiler [21] reported two cases. One of these had attracted much attention because of the complete stenosis of the larynx and part of the trachea. The patient was a young boy who learned how to fill his mouth and pharynx quickly with air and to expel it by means of the pharyngeal constrictors in such a manner as to produce sound, which was transformed into audible speech by articulation.

But of all the cases in the early literature, the most sensational seems to have been that reported by Mikulicz,[22] who performed the laryngeal extirpation, and Gottstein,[18] who further observed the patient and treated him by vocal methods. After a while the patient was able to produce a sort of hoarse tone by bending his head so that his chin rested on his chest. Later, other postures of the head accomplished the same result. The cavity above the tracheal stump had increased in dimensions by enlargement of the upper section of the esophagus. It served as a substitute source of air for activation of sound by a substitute

19. Strübing, P., and Landois: Erzeugung einer Pseudo-Stimme, Arch. f. klin. Chir. **38**:142, 1889.

20. Solis-Cohen, J.: Ein Fall von gut modulationsfähiger Stimme ohne jegliche künstliche Vorrichtung bei einem Patienten, dem der Kehlkopf und der erste Trachealring entfernt werden musste, und der ohne Kanüle atmet, Arch. f. Laryng. **1**:276, 1894.

21. Seiler, C.: A Case of Laryngeal Stenosis with Audible Articulation, Philadelphia M. Times **18**:199 (Jan.) 1888.

22. Mikulicz: Mit. a. d. Grenzgeb. d. Med. u. Chir. **12**:569, 1903.

glottis made by the lateral bands of the pharyngeal musculature and the epiglottis approximated to them. In the course of time the new vocal mechanism became more and more capable of modulation up to a point where the patient was able to differentiate a few sequences of tone. The report stated that he finally was able to sing a song within the range of an octave.

All cases mentioned were reported prior to 1903. This was about when Gluck [10] perfected his operative technic. Only a few years later, in 1908, Gutzmann [23a] reported to the International Laryngological Congress a series of more than twenty-five cases in which voice and speech developed after laryngectomy. Since that time an individual case has been reported only on occasion for some special reason, for Gutzmann and those who followed him had laid the foundation of vocal therapy and perfected it to a point where satisfactory results were regularly obtained. I shall briefly analyze the fundamental physiologic principles that serve as a cornerstone for this superstructure of vocal and speech gymnastics and describe the manner in which they can be applied.

PHYSIOLOGY OF VOICE AND SPEECH PRODUCTION

The normal person produces voice and talks by means of the lungs, larynx and the musculature used in articulation. These three units, working together, comprise the mechanism of speech. The share of the brain in the function of speech is not of concern here. The lungs act as a bellows, blowing air through the closed glottis when the cords are in position for phonation. The air from the lungs flows up to the level of the vocal cords. These it throws into vibration. This vibration, in turn, is communicated to the breath as it comes out through the closed rima glottidis. The resulting sound is called voice. This sound undergoes all sorts of modification in the resonance cavities of the pharynx, mouth and nose.

Quick, agile variations in the shape and size of these resonators by means of their mobile parts cause the formation of the different values of the consonants and vowels. In the case of vowels, the phonic expiratory stream passes unimpeded from the oral cavity. Though it can be influenced by the position of the tongue, mandible or lips, its freedom of exit is complete. To produce the consonants, however, the resonator must be so modified as to present an obstacle for the forward

23. Gutzmann, Hermann: (*a*) Stimme und Sprache ohne Kehlkopf, Ztschr. Laryng., Rhin., Otol. **1**:221, 1909. Die dysarthrischen Sprachstörungen, Vienna, Hölder-Pichler-Temsky, A-G., 1911, p. 271; Stimme und Sprache ohne Kehlkopf, I. Internat. Laryng. Kongr., 1908, p. 463. (*b*) Sprachheilkunde, ed. 3, Berlin, Kornfeld, 1924.

course of the breath to overcome. Striking against this obstacle, the breath explodes through, or pushes its way out at a point of least resistance. In the first instance the sound is explosive, in the second fricative. Adequate speech occurs only when the coordinate functions of the lungs, larynx and apparatus of articulation are flawlessly executed. How the slightest disturbance in any one of the three makes speech defective is a matter of daily experience.

Physiologic Conditions in the Laryngectomized Person.—This being the normal situation, what would be the case with the laryngectomized person? The outstanding fact is that there is no larynx. In the absence of a larynx, the bellows function of the lungs is nil, since that consists in blowing air into the larynx. The patient can continue to breathe only because a cannula has been placed in the trachea or because he inhales and exhales through the tracheostomy opening. To produce sound of any kind, one needs some vibrating instrument and something which will cause it to vibrate. In a wind instrument the cause of the sound is air under pressure, whatever its source. The human vocal organ is a wind instrument *par excellence*. Its mechanism is much more complicated than any ever devised by man. The respiratory stream of compressed pulmonic air is the force which vibrates the vocal cords. Its doing so is called "phonic expiration." Obviously, phonic expiration cannot take place in the laryngectomized person. Neither can it take place under conditions of complete laryngeal stenosis.

THE VICARIOUS AIR CHAMBER

Vicarious Phonic Air Prerequisite for Vicarious Voice and Speech.—The mechanics of voice production is due to the deep subconscious association of speech and respiratory function. This association determines the behavior pattern of all vocalization. In the laryngectomized person, however, respiration is deprived of every function but the vital. All that remains of the speech function complex is the factor of articulation. If this has not been involved in the disease, it is left intact by the operation. What, then, must be the purpose of vocal therapeutic measures in the laryngectomized person? To develop and ultimately to establish a vicarious reservoir for air which may be subjected to compression in such a way that some anatomic structure capable of functioning as a vicarious glottis may be activated by it. I shall now consider the anatomic and physiologic conditions that make such a result possible.

What and where are the anatomic structures which offer possibilities for the development of a vicarious "air chamber?" Such a chamber is

the first prerequisite. The literature up to the time of Stern's [24a] exhaustive investigations contains little or nothing of significance. As a rule, one finds only passing references to the fact that, following laryngectomy, the space which had been occupied by the larynx and hypopharynx together or in conjunction with the upper section of the esophagus becomes enlarged and accommodates much air. Gluck occasionally suggested that the stomach might play a part in the change, but the suggestion was never followed up. Even the all-embracing studies of Gutzmann made no mention of this possibility. Nothing was done until Stern, a pupil of Gutzmann, at Gutzmann's own suggestion, turned his attention to the mechanism underlying vicarious phonic respiration, especially to cases in which there was doubt concerning the anatomic factors involved. Stern began this work in 1908. There was then little material for study. Today, at the clinic of Professor Hajek in Vienna, where it was my privilege to see a great deal of Hugo Stern, there is to be found rich and productive material, which is being studied under standardized and controlled conditions. Within a few years Stern saw more than a hundred cases. It is from these that many of the facts that follow were gleaned.

The source of phonic "breath," one can reasonably assume, must lie within a space closed off on all sides. Otherwise, the compression of such breath could not occur. When compressed, it escapes at a point of least resistance. This is the point of formation of the vicarious glottis. Were this space not closed off, there could be neither compression of air nor the formation of a vicarious glottis. One of the first steps in vocal gymnastic therapy is the accumulation of air in the greatest possible quantity within such a space.

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24. Stern, Hugo: (*a*) Grundprinzipien der Sprache und Stimmausbildung bei Laryngektomierten nebst einem neuen Beitrag zum Mechanismus der Sprache und Stimme derartig Operierter, Wien. klin. Wchnschr. **33**:540, 1920; Die Funktion des Magens als Luftkessel beim Mechanismus der Sprache und Stimme Laryngektomierter, Verhandl. d. deutsch. Gesellsch. f. inn. Med. **35**:90, 1923. Weitere Untersuchungen über den Mechanismus der Sprache und Stimme Laryngektomierter, Zentralbl. f. Hals-, Nasen- u. Ohrenh. **3**:418, 1923; Beiträge zur Kenntnis des Stimm- und Sprechmechanismus Laryngektomierter, Ztschr. f. Laryng., Rhin., Otol. **12**:196, 1923; Demonstration eines Laryngektomierten mit besonders guter modulations-fähiger Stimme, Wien. klin. Wchnschr. **39**:302, 1926; Demonstration laryngektomierter Patienten (Bemerkungen zu deren kymographischen Atmungs und klanganalytischen Aufnahmen, Sitzungsb. österr. Gesellsch. exper. Phonetik. (Dec. 12, 1927), Wien. med. Wchnschr. **79**:882, 1929; Der Sigmatismus Nasalis, Arch. f. Laryng. **34**:94, 1921. (*b*) Personal communication to the author. (*c*) Wissenschaftliche Untersuchungen des Sprechmechanismus Laryngektomierter, in Denker, A., and Kahler, O.: Handbuch der Hals-, Nasen-, Ohren- Heilkunde, Berlin, Julius Springer, 1929, vol. 5, p. 494.

Location of the Vicarious Air Chamber.—The location of this space varies greatly with the patient. To find it, the method of auscultation is employed. The procedure is as follows: The patient is asked to make a sound. As he does so, the thorax is auscultated anteriorly and posteriorly so as to find the point of the sound's origin and to follow the path taken by both the swallowed or aspirated, and the expelled, air. Repeated use of this method brought to light two outstanding facts. One is that persons vary greatly with respect not only to the path taken by the air, but also to its length. Often the air may be followed as far down as the plane of the stomach. Again, it may not go below the level of the esophageal opening, that is, the cricopharyngeus muscle. The other fact is that in the majority of cases the sound seems to originate at some point in the gastric area. This is especially true during the early stages of the vocal gymnastic therapy. It should be noted, however, that errors of location often occur because sounds originating in the thoracic region are easily conducted to other points and to ears connected with a stethoscope placed over the epigastrium may easily seem to have started in the region of the stomach. Hence, auscultation of vicarious phonic respiration requires careful control and repeated checking. Both the front and the back of the thorax must be auscultated. Usually the most reliable results are obtained by auscultating posteriorly, a little to the left of the vertebral column.

Another valuable aid in studying the development of the vicarious air chamber is examination by the roentgen rays. Stern made his systematic and detailed investigation of the problem which he began many years ago chiefly with these rays. The roentgenologic study of a large number of laryngectomized persons, the behavior of whose hypopharynx, esophagus and stomach received careful attention, showed that in the great majority of cases the gastric air bubble normally contained within the stomach had undergone enlargement. Many of these cases showed a variety of changes in the bubble accompanying the act of speaking. Recent investigations, notably those of Schilling,[25] Göbell,[26] Kaplan,[27] and Voorhoeve,[28] confirm this observation. Göbell, who observed laryngectomized persons by means of the roentgen rays during and imme-

25. Schilling, R.: (*a*) Ueber die Pharynx und Oeosophagusstimme, Zentralbl. f. Hals-, Nasen- u. Ohrenh. **9**:893, 1927. (*b*) Schilling, R., and Binder, H.: Experimentalphonetische Untersuchungen über die Stimme ohne Kehlkopf, Arch. f. Ohren-, Nasen- u. Kehlkopfk. **115**:235, 1926.

26. Göbell: Stimmbildung nach Kehlkopfexstirpation, Deutsche med. Wchnschr. **50**:1234, 1924.

27. Kaplan, S.: Zur Frage der Stimmbildung bei Laryngektomierten, Festschr. dreizigjährigen Jubiläum von Prof. L. Lewin, abstr., Centralbl. f. Hals-, Nasen- u. Ohrenheilk. **8**:716, 1926.

28. Voorhoeve, N.: The Stomach as Vicarious Air Chamber Following Laryngectomy, Acta radiol. **7**:587, 1926.

diately following the drinking of seltzer water stated that the gas which is in this way "bolted" into the stomach is utilized for the production of voice, the pseudoglottis being formed by contraction of the pharyngeal musculature. Kaplan agreed that the stomach is the chief source of motivating power for the production of speech in the larynxless person. Voorhoeve, who holds the same opinion, added that the inflation of the stomach with air is due not to active deglutition but rather to a process of inspiratory aspiration followed by controlled expulsion, making the air available for speech. Controlled expulsion is the equivalent of expiration. To support this contention, he referred to the mechanism of spastic aerophagia as described by Linossier, who believes that in all probability there is an active opening of the oral portion of the esophagus as well as of the cardia. The literature is full of reports about the function of the stomach as a vicarious air chamber. The details are similar. They need no further mention here.

THE GASTRIC AIR BUBBLE

Physiology of the Normal Gastric Air Bubble.—To grasp fully how the stomach assumes this vicarious function, one needs to have in mind the physiology of its normal air bubble. The form and size of this bubble of air varies in every person with the amount and character of the gastric contents. Eisler and Kreuzfuchs [29] showed that when the stomach is empty the air bubble becomes round and about the size of a cherry stone. After a bismuth meal is taken, however, the bubble assumes the general form of a segmented arc, with a radius varying because of irregularities. When the gastric content is being evacuated the bubble tends toward a cylindroid or ovoid shape, the horizontal diameter growing smaller and the vertical diameter growing greater. Opinions differ as to the function of the bubble. According to Groedel,[30] the purpose of the bubble is to facilitate the entry of food into the stomach, the bubble acting merely as a regulator of spatial capacity. Forssell,[31] on the other hand, ascribed a mechanical purpose to it—the regulation of pressure when the lower part of the stomach contracts.

The Gastric Air Bubble Under Pathologic Conditions.—In gastroptosis the bubble is exceptionally small. Some hold that this is due to the fact that in this condition the fornix is pulled downward and decreased in size because of downward traction exerted by the gastric contents.

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29. Eisler, F., and Kreuzfuchs, S.: Die Bedeutung der Magenblase, Wien. med. Wchnschr. **62**:2951, 1912.

30. Groedel, F. M.: Grundriss und Atlas der Röntgendiagnostik, Munich, J. F. Lehmann, 1914.

31. Forssell: Ueber die Beziehungen der auf Röntgenbildern hervortretenden Formen des menschlichen Magens, München. med. Wchnschr. **59**:1588, 1912.

The great majority of cases of gastrectasia also show a small air bubble. As Faulhaber [32] demonstrated, the fornix often contains an astonishingly small amount of air, in spite of the ectasia. In cases in which the stomach is atopic (atonia) the air bubble is abnormally large, often being extended into a pyriform shape. This is thought to indicate a state of habituation, the atonic gastric musculature having been weakened to a point where it can no longer effect the expulsion of the contained air.

Index of Enlargement.—It is thus evident that the form and size of the bubble are subject to wide physiologic and pathologic variation. But there is less unanimity regarding the variations in size. The measurements give an average width of 6 cm. and an average height of 5 cm. Percussion is used to discover whether the air bubble is enlarged, and dimensional relations are revealed by roentgenograms, with special reference to the left diaphragmatic cupola. Palpation can be used when the bubble causes a marked degree of pouching. In this condition the bubble feels cushion-like to the palpating fingers. This is sufficient to indicate enlargement. Percussion and roentgenograms afford excellent means of outlining and depicting the bubble. In the great majority of cases of enlargement the left diaphragmatic cupola lies higher than the right. This alone, without any definite increase in the external dimensions, as indicated by palpation or outlined by percussion, often leads the internist to diagnose an enlarged bubble.

Effect of Vocal Therapy.—Stern's [24a] laryngectomized subjects showed an increase in the size of the gastric air bubble as the result of vocal gymnastic therapy. The width of the bubble varied from 12 to 18 cm., the height from 6 to 14 cm. The enlargement seemed to have occurred more or less suddenly, only a few days after the vocal therapeutic management had been started. Compared with the average size obtaining under normal conditions, as has been cited, the increase is considerable. The figures represent measurements made over varying periods and at different times. The patient was first examined immediately after admission to the hospital, before any operative work had been performed; again after the first stage of laryngectomy—tracheotomy; once more two weeks after the extirpation of the larynx, and finally a day or two before the beginning of the vocal gymnastic therapy.

That the stomach serves in all cases as a vicarious air chamber is not implied. Cases in which the hypopharynx or the esophagus is involved are well known. In such cases little or no enlargement of the bubble is demonstrable. On the other hand, there are cases in which enlargement of the bubble can be demonstrated before vocal manage-

32. Faulhaber, M.: Die Röntgendiagnostik der Magenkrankheiten, Samml. zwangl. Abhandl. a. d. Geb. d. Verdauungs-u. Stoffwechskrankh. **4**:no. 1, 1912.

ment is undertaken. What this may signify is as yet problematic. Considering how one organ takes on the function of a lost organ and does its work, it is difficult not to infer a natural teleologic adjustment. In the case of the stomach, the physical conditions are such as to lead almost mechanically to this organ's acquiring the function of both an air chamber and a bellows when normal phonic respiration is lacking. The presence of an enlarged gastric air bubble in some cases before the beginning of vocal gymnastic therapy may be associated with the fact that many patients who for some time after the operation can communicate only with paper and pencil can be seen to execute reflex movements of deglutition when those are not available. This may also be what enables patients who have never had any sort of phonetic therapy to learn to speak with a fair degree of accuracy. The manner of feeding the patient may be another possible cause of an enlarged gastric air bubble. The tube used naturally necessitates the swallowing of much air as well as food, and hence enlargement of the bubble follows. Against this may be set four cases observed by Seemann [33] at Kutvirt's clinic in Praha, which did not show much enlargement. This makes the question of expansion of the gastric air bubble a controversial one. It is possible that differences in surgical technic may lie behind these differing observations. Differences in surgical technic, although not significant in general, may exert much influence on function. For example, each clinic has its own type of pharyngeal suture and manner of supplying the pharyngeal mucosa, etc. Cases like Seemann's are not infrequent. I have observed a number of cases in which structures other than the stomach functioned as vicarious air chambers. These negative findings, however, have no logical veto on the numerous positive findings in the patients examined by Stern. Considering that the operative technic and the manner of feeding differ at the different clinics and that Seemann neglected to compare the planes or respective heights of the diaphragmatic cupolas, which is important in estimating the size of the bubble, a possible source of error becomes evident. Since Seemann gave the horizontal dimensions in two of the four cases as 8 and 7.6 cm., respectively, enlargement of the bubble was likely. These measurements occur only rarely under normal conditions and almost invariably indicate extension beyond the physiologic limit already described.

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33. Seemann, M.: Řeč a hlas bez. hrtanu a jejich vznik, Časop. lék. česk. **61**: 369, 1922; O dychacích a fonačních pohybech Oesofaga, Praha, 1924; Transoesofageální Registrace pohybu srdečnich., Praha, 1924; Experimentální a fisiologické studié ke vzniku řeči bez hrtanu a zvlašt řeči oesofageální, Praha, 1924; Phoniatrische Bemerkungen zur Laryngektomie, Arch. f. klin. Chir. **140**: 285, 1926; Registrierung oesophagealer Phonationsbewegungen, Vox, 1927, no. 9.

I believe that the type of vocal gymnastics applied plays an important rôle in enlarging or failing to enlarge the gastric air bubble. In all probability, its influence is greater than operative technic, feeding, constitutional predilection, etc. Is it not reasonable to assume that a patient who is taught to swallow air for the purpose of voice production, will, in time, be able to accommodate more air in the gastric cavity than the patient who is taught to aspirate air without swallowing it? Seemann did not believe that the gastric air bubble takes part in the act of phonation. Although he admitted that he had observed enlargement of the bubble at the beginning of vocal gymnastic therapy in three of twenty cases, he attributed the enlargement to mechanical aerophagia representing an expression of air from the esophagus into the stomach as the result of respiratory movements. He stated that he was never able to observe the utilization of this air for phonic purposes. During the injection of barium sulphate paste the bubble was seen to enlarge after each deglutition. Seemann contended that this was due to the fact that the barium sulphate kept on pushing the air contained within the esophagus below it into the stomach. The fact that a column of barium sulphate invariably remained in the diaphragmatic section of the esophagus, thereby for all practical purposes hermetically sealing the upper gastric outlet, is offered as a sufficient basis for the contention. Any regurgitation of air from the stomach, he claimed, would undoubtedly have made itself manifest, and he did not notice any.

This view is logical. I believe that the whole matter rests more on the manner of applying the vocal gymnastics than on other factors. Some clinics advocate the swallowing of air, which necessarily is taken down into the stomach. Other clinics advocate the aspiration of air into the esophagus. I have found the latter course much more effective and more practical for the patient. However, the situation is by no means unambiguous. Many of the facts involved are not as yet known, and when one method should be preferred to another is still problematic. Each case presents its own problem and must be studied individually and treated according to its needs. The fact that Stern teaches his patients to swallow air into the stomach, while Seemann teaches his to aspirate it into the esophagus is, in my opinion, the source of their theoretical differences and not vice versa. So much is certain: Should the aspiration method be applied, phonation must occur simultaneously with the aspiratory process, for if respiratory movements occur between, the aspirated air reaches the stomach in the manner described by Seemann and causes enlargement of the gastric air bubble.

Of course, Stern's statistics cannot be taken as the final word in the matter of enlargement of the bubble, for even though a hundred odd cases are a goodly number, the collected material of the world would be necessary for any ultimate conclusion. Yet these statistics are not

to be dismissed with a mere reference, for Stern studied enough cases to indicate the degree of probability with which enlargement of the air bubble is likely to occur. This is about 50 per cent in his own series, and he assumed that the stomach acts as a reservoir for air in as many as 70 per cent of all cases, especially in the beginning of the vocal gymnastic therapy. He based his assumption on his roentgenologic investigations.[34] He went further in an effort to prove this point. He made the interesting observation that often a patient who, for some reason, had to remain silent for a long period, showed under fluoroscopy a somewhat lower left diaphragmatic cupola than when he had been phonetically active. When the left diaphragmatic cupola was lower the condition was presumably due to phonic inactivity, since the deglutition of air and its subsequent use for speech causes heightening of the cupola and simultaneous enlargement of the gastric air bubble. Stern considered this as direct evidence of the association of this part of the stomach with the process of vicarious phonation. He sought further proof of this contention in the patient's reaction to the ingestion of carbonated water. After the intake of the fluid, the air bubble was seen to enlarge as the result of the fluid's gaseous content, and rarefaction could be observed fluoroscopically (a lighting up). The patient who before taking the fluid had been able to produce but few syllables with a single expiratory effort could now produce a greater number. The added power was attributed to the increased amount of gas in the stomach. The fluoroscope also showed the stomach diminishing in size in a sort of collapse, becoming much smaller than before the intake of the fluid. This collapse occurred especially when the patient was instructed to put all his efforts into producing sound, yet not to swallow any air. In four of six laryngectomized subjects who cultivated "voice" spontaneously, Stern found the vicarious source of air also to be the stomach. Why this should happen in some cases and not in others further investigation must determine.

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34. Attention has been called to the fact that the dimensional relations of the gastric air bubble are subject to much variation. Even before the application of vocal gymnastics it was occasionally found to be enlarged. In many cases in which the dimensions were normal before such application the bubble became demonstrably enlarged a few days after. The dimensions in such cases, as given by Stern, showed variations of from 7 to 12 cm. for height and from 10 to 15 cm. for width, a definite increase over the normal. In the majority of cases, the dimensions remained so. For this determination both diaphragmatic cupolas were carefully compared in respect to height. Only rarely was the plane found to be identical. Normally, the right cupola is somewhat higher than the left. As has been mentioned, the diagnosis of an enlarged gastric air bubble was considered justified when the left diaphragmatic cupola was found to be higher than the right. This was Stern's finding in the great majority of his laryngectomized subjects.

The Bubble as a Pneumonic Cushion and Its Possible Relation to an Air Chamber.—Whether or not the term bellows is properly applied to the gastric air bubble has been the subject of some discussion. The notion depends on an analogy with the musical organ, in which an actual bellows compresses the air that activates the reeds. When the gastroenterologist speaks of the bellows-like function of the air bubble he means, however, something different from what happens in the laryngectomized person. He is really speaking of regulation of pressure. It is a familiar fact that when the pipes connected with a pump are too narrow they are subject to severe stress and strain whenever there is any pumping, and that these are damaging. Wider tubes reduce the damage, but when their use is undesirable the remedy applied is the air-cushion. This device allows for a column of air above the water which flows through the pipe. This column of air acts like a spring, absorbing the kinetic energy of the stresses. The phase of the pumping during which it absorbs shocks—compression or rarefaction—further differentiates it into pressure air chamber and suction air chamber. Kreuzfuchs and Eisler [35] made a fine study of the differences. It seems that the gastric air bubble functions in both ways. On the one hand, apart from the fact that the tonus of the gastric wall itself regulates the internal pressure of the stomach, the air bubble contributes importantly to this regulation by compensating for changes of pressure due to changes in tonicity. In addition, the air bubble absorbs the stresses caused by antral peristalsis like an air-cushion through compression. But these are not functions required to employ the bubble for phonetic purposes. For these purposes the bubble serves as a reservoir for air.

Schilling [25b] reported an interesting case which illustrates how the gastric air bubble acts the rôle of a pneumonic cushion. According to Schilling, the pump action in the laryngectomized subject involves both the esophagus and the stomach. His case showed a left diaphragmatic cupola considerably higher than the right, even during rest. During phonic activity, the left cupola ascended as the bubble enlarged, the whole movement being rather jerklike. Roentgenologic examination revealed the striking fact that when phonic activity ceased the bubble became larger and longer than before. The change was so unusual as to be spectacular, other cases having shown the opposite effect. It is possible that in this particular case the gastric air bubble functioned not only as a reservoir for air but also as a pneumonic cushion, in this way sustaining adequately the necessary gaseous tension of the entire space employed for making sound. It may be that muscular contractions derived from the diaphragm and from the anterior abdominal wall

35. Footnote 29.

are transmitted to the gastric air bubble during phonic activity and compress and release it as they shut down and relax. Further investigation led Schilling to conclude that whether enlargement or diminution of the air bubble occurs depends on the degree of force applied and the order of succession of the separate factors which act to cause expulsion. This explanation, I believe, also accounts for the various findings by different observers in respect to the function of the gastric air bubble.

VICARIOUS ASSUMPTION OF THE FUNCTION OF AN AIR CHAMBER BY ORGANS OTHER THAN THE STOMACH

I have mentioned several times that structures other than the gastric air bubble may function as vicarious reservoirs of air to be used in phonation. Proper articulatory action can fill the hypopharynx and the cavity created by the extirpation of the larynx with air. This air, compressed by the contraction of the muscles of the enclosing parts, is so expelled as to be directed through a point of least resistance provided by a narrowing somewhere in the apparatus of articulation above it. The force of expulsion is sufficient to cause sound. Not infrequently this is how a "pseudovoice" is developed and maintained. When the air has been used up, it may be renewed by relaxing those parts which had contracted to compress it. The air then flows in, as in any cavity which suddenly becomes larger. This inflow of air is the equivalent of phonic inspiration. In the majority of cases, however, the mere relaxation of the parts involved cannot accomplish this. Additional movements are required, such as swallowing, sipping, etc.

Since the inflation and collapse of the air chamber defines itself clearly, the process may be followed in all its details. There are cases, as those observed by Landois and Strübing,[36] in which the upper part of the esophagus as well as the cavity in the hypopharynx serves as an air chamber. In a great number of cases, on the other hand, only the esophagus serves this purpose, in which case the act of speech is ushered in by esophageal contractions which begin at the lower end of approximately its upper third, or somewhat lower, and progress proximally in a spiral or serpentine manner. This continues until the esophageal walls coaptate, whereon renewed deglutition causes their separation. This, however, is difficult to observe even under favorable circumstances. I have followed two such cases carefully.[37] In the beginning of the vocal gymnastic therapy, before the patient has had much practice, the esophagus opens in an explosive manner. With sufficient practice, however,

36. Landois and Strübing: Erzeugung einer (natürlichen) Pseudo-Stimme bei einem Manne mit totaler Exstirpation des Kehlkopfes, Arch. f. klin. Chir. **38**:142, 1889.

37. Kallen, L. A.: Discussion of Mechanism of Esophageal Speech, Arch. Otolaryng. **15**:479 (March) 1932.

the process becomes slower and more purposeful, and much more air reaches the esophagus. These observations corroborate those noted in many cases in which the esophageal mechanism was the one involved.

Phenomenon of Esophageal Phonation.—Stupka [38] described an interesting phenomenon associated with the act of phonation. It occurs in the upper alimentary tract. The inrush of air into the esophagus when the latter is opened indicates the negative pressure within it. It follows that as the thoracic cavity increases in size during the act of inspiration the esophageal cavity enlarges also, except under forced expiratory activity, such as yelling, screaming, coughing, etc. The dominant pressure within the esophagus is always negative. Stupka noticed motor manifestations during phonation, not only at the mouth of the esophagus, where they were marked, but also in its lower parts. The manifestations consisted in variable synergic contractions, tight corset-like constrictions of the esophageal lumen in the region of the esophageal mouth and hiatus. The caliber of the lumen narrowed, chiefly in a horizontal plane.

These changes within the lumen of the esophagus were genuine active changes and are construed as physiologic in character. In general, spasms intensify the contractions, while disorders of an enervating nature accompanied by a reduction in tonicity weaken them. This phenomenon associated with phonation occurs at the areas mentioned because they consist of transverse striped musculature and receive impulses conducted along fibers given off by the vagus, superior laryngeal and recurrent laryngeal nerves. Occasionally muscular activity within the esophageal wall could be observed in the region of the hiatus and was traced to active contraction of striped muscular elements belonging to the circular layer.

Seemann [33] was the first to make a graphic register of this phenomenon associated with phonation. He used a specially constructed esophageal sound which showed that phonation contractions in the cervical and upper portions of the thoracic esophagus were genuinely active and not dependent on respiratory movement. Only in the middle and lower thoracic esophageal sections were the changes within the lumen during phonation regulated by thoracic movements incident to breathing. The cause is anatomic. The cervical and upper thoracic portions of the esophagus contain transverse striated muscle fibers; the muscles of the lower part are smooth. As the recurrent laryngeal nerve gives off branches some of which (the so-called rami oesophagei nervi recurrentis) are distributed to the esophagus, the phenomenon associated with phonation is probably the result of an irradiation to the musculature of the esophagus of the nerve impulses attending phonation.

38. Personal communication to the author; cited by Seemann [33] and Stern.[24c]

In some cases (those in which the esophagus is the vicarious air chamber) the contractions referred to exert their force for the purpose of compressing the air, while in other cases the constriction which they cause is utilized as a vicarious glottis when the source of air comes below it.

These conditions underlie the phenomena of an interesting case described by Gottstein.[8] He reported the existence of two air chambers, one constantly active, the other serving as a reservoir. If the patient paused for an instant while speaking he produced a belchlike sound. At the same time a balloon-like arch measuring from 3 to 5 by from 5 to 4 cm. appeared above the level of the tracheal stump. The behavior of this arch was carefully studied in Hirtl's laboratory. Its movements were graphed by means of a tambour which simultaneously recorded the movements engendered by speech. It was shown that the ballooning kept up, although there was no renewal of air from the outside. The inference that the upper air chamber was being fed by another somewhere below it was proved by the discovery of the lower chamber in the upper portion of the esophagus.

Observations such as these and other observations discussed in this article are best made by the roentgen rays and, whenever possible, by graphic registration. The patient's own report, however, is often reliable, and not infrequently he is able to localize objectively and with a fair degree of accuracy the feelings that accompany his new way of speaking. When such localization can be reported, it is the best clue for making research effective.[39]

FORMATION OF VICARIOUS GLOTTIS

Methods of Study.—I shall now discuss the formation of the vicarious glottis. Laryngologists are not so sure in their knowledge of this as of the vicarious source of air. The chief difficulty is due to the limitations of the methods available for examination. It is, for example, no easy matter to examine "laryngoscopically" even the patients who may have attained a mastery of the new mechanism. In fact, it is well nigh impossible, for the moment the patient tries to "vocalize," movements of deglutition or aspiration occur. These block the observation of the physical events taking place. Moreover, when such an examination is attempted, simultaneous protraction of the tongue is, for obvious reasons, impossible. Yet such protraction is necessary if the hypopharynx

39. In two instances—one case each of Dr. Alfred Lewy and Dr. Samuel Salinger, attending otolaryngologists at Cook County Hospital, Chicago (both cases were referred to me for phonetic management following laryngectomy)—roentgen investigation corroborated closely the subjective reports of localization by the patients.

is to be observed. Fortunately, cases sometimes are seen in which inspection is possible without protraction of the tongue. In the other cases auscultation is a valuable source of information, being carried out on the anterior and lateral aspects of the neck with an ordinary stethoscope. Palpation also is an aid in differentiating areas of vibration. And although the roentgen rays are not so useful here as in the study of the vicarious air chamber, they occasionally enable one to make certain inferences. In general, however, the membranous folds and the muscular bulgings involved are too slight to be distinguishable from surrounding tissue. The findings in a few patients who had cultivated fairly good voice but who had come to necropsy because of recurrence have not helped much in indicating how the vicarious glottis developed and acted. Now and then a particular point has been made, but generalizations cannot logically follow.

Anatomic Structures That May Be Involved.—There are many anatomic structures that can serve in the formation of a vicarious glottis. To enumerate them from front to back, they are: the dorsum of the tongue and the tensed velum palatini, the base of the tongue and the posterior wall of the pharynx, the two posterior pillars of the fauces (palatine arches), the inferior constrictor of the pharynx, the epiglottis and the two lateral pharyngeal bands and the external folds of the esophagus with its associated tissues (the cricopharyngeus muscle).

That the mouth of the esophagus can function as a vicarious glottis was much discussed and established many years ago. A case in which much is made of the rôle played by this structure was described by Bandler.[40] Fraenkel,[41] in making a study of the case of Strübing and Landois, showed that the voice was engendered in the upper portion of the esophagus by the external folds. Gutzmann [23a] corroborated this. In 1914, Fröschels [42] observed a case in which the force of muscular contraction caused the expulsion of air through a narrow slit in the upper part of the esophagus and the hypopharynx. A thorough study of the problem involved, however, was first made by Seemann,[33] who cleared up many points. His investigations led him to the conclusion that the anatomic and physiologic conditions of the esophagus perfectly

40. Bandler, Adolph: Ueber die Sprachbildung bei luftdichtem Kehlkopfverschluss, Ztschr. f. Heilk. **9**:423, 1888.

41. Fraenkel, B.: Berl. klin. Wchnschr. **30**:758, 1893; Zur Regeneration exstirpierter Stimmlippen, Arch. f. Laryng. **20**:98, 1908.

42. Fröschels, Emil: (*a*) Sprechen ohne Kehlkopf, Wien. med. Wchnschr. **64**:150, 1914; (*b*) Ueber Oesophagusatmung eines Laryngektomierten, Wien. med. Wchnschr. **76**:875, 1926; (*c*) Sprachheilkunde (Logopädie), Vienna, Franz Deuticke, 1925; (*d*) Ein Fall von Oesophagusatmung und Oesophagusstimme nach Kehlkopfexstirpation, Wien. med. Wchnschr. **78**:1434, 1928.

meet the requirements for the production and development of voice in laryngectomized persons. His study was made chiefly by means of roentgen examination, in collaboration with Köhler, roentgenologist at the Kutvirt clinic in Praha.

Mechanism of Speech with Esophageal Glottis.—Two stages can be differentiated in the production of esophageal speech. The first is the oscitance (opening up) of the esophagus before phonation occurs. The second is esophageal contraction during phonation. Air can rush into the esophagus only after its mouth is opened. Under ordinary conditions of normal respiration, however, the esophageal orifice is kept tonically closed. It opens reflexly only on swallowing and vomiting. This is why it is impossible for large amounts of air to rush in during the act of inspiration. That can happen only when the tonic closure is released. Examination during quiet breathing reveals a closed orifice. A few cases of an open one have been reported. Burger,[43] among others, has reported such a case.

Normally, the esophagus, which contains a negative pressure during the act of inspiration, remains closed. For the successful aspiration of air into the esophagus, therefore, another mechanism is necessary. The laryngectomized subject has to learn the method of effective aspiration of air into the esophagus by means of conscious sensibilities located in the parts involved. In the beginning, the process is accompanied by a belchlike sound, which is caused by friction of the air current and the dishesion of the esophageal walls. The process of aspiration is best followed by placing the back of the hand on the under surface of the chin (floor of the mouth) and on the anterior surface of the neck (region of the larynx). The moment the aspiration sound occurs tension of the oral floor can be felt. At the same time the larynx obviously executes a jerklike movement upward and forward. The cause is contraction of the thyrohyoid muscles. This pulls the larynx away from the posterior pharyngeal wall at the same time. The force of this upward and forward pull is simultaneously distributed to the cricopharyngeus muscle, which forms the anatomic substratum of the esophageal orifice, and the tonic closure of this muscle is relaxed. During the movement a quick short inspiration caused by a jerklike contraction of the diaphragm starts a rush of air into the esophageal vacuum and produces the acoustic effect described. As the patient becomes more proficient through practice, he is able to accomplish the aspiration more completely and with less effort. The process then becomes less noisy or, in some cases, even noiseless.[37]

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43. Burger, H.: Voice After Removal of Larynx, Nederl. tijdschr. v. geneesk. **67**:303, 1923; Speech Without a Larynx, Proc. Roy. Soc. Med. **5**:6, 1925.

A Definite Vicarious Glottic Entity Not Necessary.—Occasionally the vicarious glottis is not a definite entity. As may happen normally, eructation combined with articulation is sufficient to produce vicarious speech. Many cases have been reported in which voice is produced without a definite vicarious glottis, the simultaneous development of belching and articulation being sufficient. That it can and does occur one may easily demonstrate on oneself. Often patients begin to speak in this way and go over to another mechanism based on the development of a glottic entity gradually through practice.

Location of the Vicarious Glottis.—The conditions that determine where the vicarious glottis may develop vary considerably. There is no hard and fast rule, and generalizations are not justified. An important factor is the position of the vicarious air chamber, which must necessarily be below the newly acquired glottis. The new relation between parts resulting from laryngectomy also plays a significant rôle. The surgeon should be interested in preparing the patient as favorably as possible for the phonetician. He should save as much tissue as is safely possible. In the desire to be absolutely sure that no diseased portion remains he often removes demonstrably sound tissue, such as muscular tags, folds of mucous membrane, etc. Such removal is to be regretted. It should be performed only when doubt as to the health of the tissue makes it imperative. Every fold of mucous membrane, every favorably placed cicatricial band, every muscle or muscular remnant, may serve as the basis for the development of a pseudoglottis. What or where they should be cannot be stated in advance. The vicarious expiratory current of breath selects, on the physical principle of efficiency and mechanical advantage, that structure which, in resistance to it, will best meet the mechanical principles involved—in other words, that structure offering the best tool for the maximal production of useful sound with minimal force. Many a striking case of pseudovoice owes its development to the hand of the watchful surgeon.

Influence of Postoperative Anatomic Relations on Formation.—Can a pseudoglottis be surgically predetermined and inserted? It has been suggested that transplanting two folds of mucous membrane or muscular strips in the mesopharynx or hypopharynx might provide a structure which might later develop into the pseudoglottis. What is anatomically possible has already been discussed. It seems to me that these possibilities should receive consideration also from the standpoint of surgery. The position or direction of the transplanted folds that are intended to function as the future vocal organ is not a matter of importance. What counts is their capacity to vibrate. Only long experience and eternal vigilance along these lines can teach one ultimately how to improve and perfect the formation of a pseudoglottis. The

surgeon should exercise the greatest care during the operation to spare the fibers of the cricopharyngeus muscle. Much of the damage which it sometimes receives can be avoided by dissecting it away from the cricoid cartilage. Not only is it of the utmost importance that this structure escape all injury during operation, but the integrity of its innervation must also be preserved. Lacking that, it cannot properly function as a pseudoglottis. The esophageal branches of the recurrent laryngeal nerve must be spared as much as possible. For technical reasons, it is not possible to retain the external branches of the superior laryngeal nerve, though these are also involved in the innervation of the cricopharyngeus muscle. Saving the esophageal orifice from surgical harm is an essential precaution. In addition, it is important to protect the sternohyoid and thyrohyoid muscles. These muscles pull the larynx upward and forward, lifting it away from the posterior wall of the pharynx, thereby relaxing the tonic closure effected by the cricopharyngeus muscle—an important movement in the training of esophageal speech. Finally, the phonetician would ask the surgeon to sew the sternohyoid and the thyrohyoid muscles to the anterior wall of the pharynx, approximately at the level of the mouth of the esophagus. This facilitates the mechanism of aspiration.

CLASSIFICATION OF PSEUDOVOICES

I have considered how the different forms of pseudovoice may arise and on what basis they are classified. However, in the light of the records of the cases studied, the classification of mechanisms producing vicarious voice and speech should be made with great caution. They and all factors associated with them, such as vital respiration, may undergo modification or complete metamorphosis over a long period. Mixed types occur. Normal mechanisms and vicarious mechanisms are sometimes found side by side.

For the purpose of practice, however, four chief groups can be differentiated in terms of the anatomic structures involved in their production. Thus, one speaks of the pseudowhispered voice, the pharyngeal voice, the esophageal voice and the gastric voice.

The Pseudowhispered Voice.—The pseudowhispered voice has been called whispered speech and oral speech, to distinguish it from pharyngeal speech. The term "whisper" is certainly not consistent with the existing facts, for whispering is an action of the larynx. Normally, whispering occurs when the expiratory breath current flows through the posterior portion of a rima, making an opening shaped like a triangle and varying in size. In cases of transversus paresis or paralysis of the posterior triangle, the part of the rima which constitutes the cartilaginous portion of the glottic chink remains open and causes

the familiar husk in the voice due to the admixture of noise with tone. The noise originates in the open posterior triangle, the tone in the intermembranous part of the chords.

A similar effect is also seen in internus paresis, the intermembranous part of the chink being too open for perfect tonal effect. Under normal conditions of whispering, the rubbing of the forward moving breath against the resisting glottis is such that instead of throwing the cords into vibration and producing voice, it merely sets up a friction sound. This sound, really a noise, is the so-called normal whispered voice. Naturally the laryngectomized subject cannot make it. His "whispering" is due to compressing the air contained within the oral cavity when articulation functions to produce consonantic values. Consonants can be produced only when there is somewhere in the oral cavity an obstacle, complete or partial, to the forward coursing breath which is compressed sufficiently to overcome that obstacle. With vowels, which have free unimpeded exit, the case is different. The laryngectomized subject who "pseudowhispers" cannot form independent vowels. He can merely indicate the vowel. He does this by assuming the oral posture involved, whereas he actually produces the consonant. He produces unvoiced consonants but represents vowels and other vocular values by their articulatory formations. For this reason, pseudowhisper and not pseudovoice is more descriptive of what he does. It occurs spontaneously soon after operation. Although it is more or less audible, it can even under the most favorable circumstances be understood only when the listener is very near and pays the closest attention. This way of speaking has also been called silent speech, oral voice, and consonant speech. Pseudowhisper, however, covers them all.

The mechanism of the pseudowhisper was studied long ago by Bose,[44] Czermák,[1] Gutzmann [23] and a host of others. Bose described how patients manipulated the walls of the space containing the air which produces sound. He found that air was forced through a part of the mouth narrowed or closed in an articulatory posture by quick forward traction of the hyoid bone, which carried with it the floor of the mouth, especially the posterior part of the tongue. Naturally the loudest and clearest consonants have their genesis in the anterior part of the oral cavity, since the amount of sound-producing air increases as the position of the zone of articulation advances. Bose reported the case of a patient who was able to whistle thus. Gutzmann tried this method on himself and found to his great surprise that after a little practice he could emit whistling tones with the glottis closed. This practice is more or less common among laryngectomized persons. Stern [24b]

44. Bose, H.: Die Verengerung und Verschliessung des Kehlkopfes, Giessen, W. Keller, 1865.

repeated Gutzmann's experiment. He found that during the attempt to speak while the glottis was under forced spastic closure and breathing was completely arrested, a few sounds and short syllables could be produced and recorded graphically. The mouthpiece used was purposely not made air-tight, so that alterations of air pressure could constantly compensate themselves without any hindrance. Nevertheless, a condition of negative pressure was frequent. Gutzmann investigated also the amount of air emitted at the three zones of articulation, making his determinations by volumetric measurements of the air expelled from the oral cavity. He purposely chose sounds other than the explosives P, T and K, because he feared that those would register graphically not only volume of air but also muscular action. He therefore tested the friction sounds corresponding to the three zones, respectively, these being F, S and the posterior CH (German). Graphic representations of these sounds revealed that they are always made together with an initial explosive sound corresponding to the particular zone used. They occur, thus, not as F, S and CH, but as pF, tS and kCH. In the experiment, the patient spoke into an air-tight mask placed over the nose and mouth. The volume of air expelled from the mouth was found to be about the same, whatever the zone of articulation from which it was emitted. Gutzmann believed that this was due to the identical character in each case of the movement of the oral diaphragm which expelled the air contained in the oral cavity, whatever zone was in action, the entire volume of oral air being thus set in motion. It must, however, be remembered that the soft tissue of the cheeks, to which the air-tight mouthpiece was adjusted, responding to the increased intra-oral pressure, would naturally give a little. This means that not the entire volume of air utilized was measured. Gottstein's experiments gave much smaller figures than Gutzmann's—about 30 cc. to Gutzmann's 50. Later, Gutzmann modified his technic. He had the patient blow into a tube placed between the lips. He connected the tube with a graduated cylinder filled with water and placed upside down as a pneumatic bridge. This device registered an increase in volume. If the subject held his mouth open before expelling air, the volume increased considerably. In testing the second zone of articulation, the tubal mouthpiece was set between the lateral margin of the tongue and the alveolar process of the maxilla, and the patient was instructed to blow as before. The volume was found to increase as the base of the tongue was lowered before the actual blowing. The third zone could not be tested successfully because the tubal opening could not be kept air-tight. The average figures resulting from numerous examinations made by various observers come to about 100 cc. for the first zone of articulation and less than half of that for the second. One may thus infer that the conditions of pressure

grow worse as the zone of articulation recedes into the oral cavity, and enunciation grows correspondingly blurred. The posterior CH (German) is the hardest sound to produce. M, N and Ng usually emerge in the form of their explosive equivalents (B, D and G). L is made by a friction sound originating between the base of the tongue and the alveolar margin of the maxilla. As a rule, it is unilateral, a bilateral formation requiring too much air. R can be formed labially, lingually, palatally or with the uvula, but because of its tonelessness it does not sound characteristic.

While the consonants are pronounced with only partial success, the vowels, as has been noted, cannot be produced. If, however, a tonal element is introduced into the oral cavity from the outside, vowels can be sounded, which are determined by the oral posture at the time the tone is produced. Deleau,[45] Czermák and others experimented with this long ago, and Gluck [10] adapted it to his special laryngeal prosthesis. The patients instinctively and spontaneously adapt their articulation to it. Nevertheless, genuine vowel formation does not occur. What really happens is that the consonant with which the vowel is combined provides an impetus to vowel-forming vibrations within the resonator. Stern has referred to this phenomenon as "consonantic co-traction of vowels." It can be perfected to a point at which speech can be heard clearly at a fair distance.

Disadvantage of the Pseudowhisper.—A patient in whom the pseudowhisper has become habitual finds the further mastery of larynxless speech by vocal methods extremely difficult. A short period of practice conditions him to the former method, and he finds that the beginning of vocal gymnastic therapy presents greater obstacles than would otherwise be the case. His habit causes constant interference, so that the new mechanism establishes itself poorly, if at all. It is, thus, of the utmost importance to warn the patient earnestly not to use this way of speaking and to urge him to make every effort to avoid it. Until such time as he begins vocal gymnastic therapy it is far better for him to use pencil and paper.

The Pharyngeal Voice.—Every patient whose vicarious glottis lies in the mesopharynx or hypopharynx speaks with a so-called pharyngeal voice. The properties of this voice and the elements of its mechanism have already been discussed.

The Esophageal Voice.—The esophageal voice differs from the pharyngeal voice not only in mechanism but in acoustic quality. The glottis lies at a much lower level in the former than in the latter. It occurs either at the base of the hypopharyngeal cavity (where it makes

45. Cited by Stern.[24e]

a transition into the esophagus) or within the esophagus itself (the esophageal mouth). The vicarious air chamber associated with it is developed below it and functions by dilating and contracting. Thus, the entire act of vocalization takes place within the esophagus itself, as has been described in the section on the mechanism of speech with the esophageal glottis. To bring this about in the patient is, in my opinion, the aim and end of vocal therapy for laryngectomized persons and the ideal for which such a patient should strive and work. It is the manner of voice production which gives the most satisfactory results, not only for volume but also for modulation and fluency. Of course, the attainment of this end is not in every case possible. Sometimes not all the necessary factors are available, and then one must do the best one can with those that are present. Not infrequently a pharyngeal voice passes gradually over into an esophageal voice. The phenomenon seems to be connected with what Stern called "migration of the air chamber," which I shall presently describe.

The Gastric Voice.—In gastric voice the gastric air bubble functions to produce vicarious speech and the factors that enter into its mechanism. This is the mechanism which ventriloquists often use.[46] A person listening to this sort of voice, even when totally unaware of how it is produced, gets the impression of a "belly-clang." It is well known that many ventriloquists produce their effects by processes entirely different from the usual ones. These processes include tension of the palatine arches, differences in the economy of the phonic breath and in the manner of articulation, etc. Cases are rare in which the spasmodically closed-off larynx in no way enters into the production of the sounds and the ventriloquial effect is produced by means of the stomach, esophagus and some of the factors of articulation. But they do occur, and the sound is made as by a laryngectomized subject. In many such subjects a pseudoglottis seems unnecessary. The sound made by eructation from the stomach, combined with articulation, is sufficient to produce speech.

Transition from One Type of Pseudovoice to Another.—I shall now consider the so-called migration of the air chamber already referred to in connection with the transition of voice. I have already mentioned cases in which the air chamber at the beginning of vocal gymnastic therapy was demonstrably an enlarged gastric air bubble, which was observed to grow gradually smaller as the therapy progressed. Often the bubble decreases thus to normal dimensions. Auscultation during the act of swallowing and then expelling air shows that the path which the air takes is shortened. The vicarious air chamber gradually ascends from the stomach to the esophagus and even to the hypopharynx. This may

46. Flatau, T. S., and Gutzmann, H.: Die Bauchrednerkunst, Leipzig, Abel, 1894.

be due to the fact that a beginner, in learning to accumulate and retain as much air as possible within the stomach through the process of deglutition, is apt to overdo the process. He uses more energy than is necessary and thus forces the extent of deglutition. With practice, however, he finds himself able to convert the air into sound much more quickly. No sooner is the air swallowed than it is transformed into audible speech. Practice renders the path of the air ever shorter, until the air is transformed into the pseudovoice automatically with the swallowing. When such a patient is reexamined after an interval of months, the character of the voice is observed to have changed, the fluency and whole manner of speech being noticeably improved. Close examination reveals the air chamber in the upper part of the esophagus.[47]

VICARIOUS SPEECH AND RESPIRATION

Variations in the Dissociation Process of Respiratory Function.—Occasionally one also sees variations in the dissociation which the laryngectomized subject who is endeavoring to master the new speech mechanism must learn. Larynxless speech, however, does not always require dissociation from the normal phonic respiratory movement.

Fröschels [42] described a patient whose intake and output of phonic air was greatly helped by the normal respiratory movement of the thorax and diaphragm with their respective pulmonic expansion and contraction. Occasionally this process develops spontaneously in esophageal speakers. Normal breathing, which is not ordinarily employed by the laryngectomized persons who have acquired the new way of speaking, may yet be brought into its service. Fröschels' patient, whom I had occasion to examine personally in Vienna in 1928, was able to produce six syllables without renewing "breath," and could speak inspiratorily as well as expiratorally, with great benefit to his fluency. Examination showed him to have a real esophageal voice. At first this pseudovoice came only after the deglutition of air. After a few weeks the patient could produce it by aspiration into the esophagus, at the same time articulating it into meaningful sounds. Aspiration was accomplished by a jerklike inspiratory movement of the lower part of the thorax and sudden protrusion of the anterior abdominal wall. Graphic registration of these movements showed that the aspiratory and the expiratory sounds corresponded to the movements of normal phonic respiration. On roentgenologic examination the "act of speech" was shown to possess two phases, both accompanied by sound. In the first, the diaphragm descended with inspiration, the walls of the esophagus diverging as its lumen underwent dilatation on filling with air. This was the phase of inspiration-

47. Patients have told me that they no longer needed to draw the air from so great a depth as before.

aspiration. The second phase consisted in ascent of the diaphragm and expiration. This was accompanied by gradual approximation of the esophageal walls and contraction of the lumen simultaneously with the depletion of its gaseous content. It was the phase of expiration-expulsion. The gastric air bubble was not essentially enlarged. Neither its size nor its density showed any changes during the movements described. I was able to set up this sort of movement in one patient at the beginning of therapy. Within a month this patient cultivated an excellent articulated voice mechanism characteristic of the esophageal voice which has already been described.

The use of normal respiration in larynxless speech was also observed by Burger and Kaiser,[48] who reported an interesting case. They suspected that in many cases of esophageal voice respiratory movement plays an important rôle. Their own case showed an active opening of the cardia, such as can occur only during vomiting, swallowing or eructation. They considered this an element of a newly learned function complex which, as a whole, is complicated. From the fact that their patient was able to produce an effortless G, they deduced that the tongue could not be involved in the formation of the pseudoglottis. H was difficult, because it calls for a great volume of air to sound. There were special respiratory movements at the nasal entrance and in the upper thoracic, the gastric and the abdominal, regions. A record of the movements of these areas was made by the pneumograph, which showed four simultaneous curves. The nose was shown to play a greater part than is commonly supposed.

Inferences as to Respiratory Function Based on Statistical Data.—The way of breathing during the new speech process has been carefully studied by a number of observers, notably Stern.[24a] It has already been noted how great is the handicap to the laryngectomized person, as compared with the normal speaker. The study of breathing showed why the avoidance of synchrony between the natural act of respiration and the learned act of the swallowing or aspiration of air is of such great importance. When these two acts are performed at the same time not only is the vocal sound obscured by the adventitious sounds due to the friction of air passing through the tracheostomy opening, but severe coughing may be induced. Even when other factors are equal, this condition calls for special attention during the early stages of vocal therapy. Although not all the data on respiration during vicarious speech have yet come to light, the facts known may be summarized as follows:

1. Types of phonic respiration in laryngectomized persons can be definitely classified.

48. Burger, H., and Kaiser, L.: Speech Without a Larynx, Acta oto-laryng. 8:90, 1925.

2. Two main types of phonic respiration seem to predominate. In one, the process of breathing is normal. In the other, renewed respiration occurs with each word, often with each syllable; in this type the interference with the new speech mechanism by ordinary vital respiration seems to persist.

3. A number of forms, both mixed and transitional, fall between the two main ones.

4. In a great number of cases, the pneumograph provides a clue to the location of the vicarious air chamber and the pseudoglottis. The lower these two structures lie the more marked the abdominal component of respiration is likely to be. The higher they lie, the more the thoracic element is likely to play a part in the new way of speaking. This follows if one or the other component of respiration serves as an aid in "expression" of air necessary to activate the pseudoglottis.

5. The type of phonic respiration in the laryngectomized person may change with time and come to a certain stability only after many years. The change may be connected with the migration of the air chamber and with such factors as concern facilitation of the neuronic pattern, etc.

These findings summarize Stern's [24c] statistics and are reenforced by the great number of cases examined by Schilling.[25]

The Rôle of the Diaphragm in Vicarious Respiration.—The general view is that the diaphragm plays a much greater part in the new speech mechanism than is supposed. In a certain sense the two reservoirs for air (the lungs and the vicarious air chamber) interfere functionally. Fluoroscopy shows peculiar jerklike movements of the diaphragm, which in selected cases obviously serve to compress the distal end of the esophagus or the gastric air bubble proper, thus aiding in the expulsion of air. That these movements have no connection with vital respiratory function is proved by the fact that they are seen to occur also when the tracheal cannula is shut off. It would follow that the diaphragm functions as an auxiliary in the new speech process, but otherwise than in normal speech.

Schilling [25] and Stern [24c] independently reported similar observations of the behavior of the gastric air bubble. Under fluoroscopy the air bubble was seen with each sound made to expand and contract simultaneously with the ascent and descent of the diaphragmatic shadow, which recovered its former place and dimensions. A thorough search was made for movements of respiration during the production of the pseudo-voice. Almost complete immobility of the thorax was found. Schilling and also Fröschels attributed this to the patient's effort to diminish as much as possible the noise attending expiration.

A superb physiologic study by Dahmann [49] showed how breathing affects the lumen of the esophagus. Dahmann was disinclined to draw definite conclusions, because he believed that the technic of registering by inserting, for example, a small balloon into the esophagus, obscures or interferes with many normal processes. However, in essence, his findings concerning the way the speech mechanism works in a great many laryngectomized subjects corroborate those of the other investigators. Thus, Schilling had found that the phase of diaphragmatic descent is used for the purpose of expressing air from the stomach, and Stern, much later, reported similar observations on two patients of his own. Dahmann's work provides an adequate explanation for the situation. Although he referred to normal speakers, what he wrote applies to the vital respiration of laryngectomized subjects also. He demonstrated that the normal process of respiration has an effect on the abdominal part of the esophagus which is opposite to that on the thoracic portion. In the abdominal part of the esophagus inspiration causes narrowing of the lumen, and there is an increase of pressure. In the thoracic portion the lumen dilates, and the pressure decreases. Expiration reverses these consequences. In sum, there is complete inversion of respiratory typing and rhythm. Schilling regards this inversion of coordination as forced.

SPEECH MELODY IN THE LARYNGECTOMIZED

Bases for Modulability of the Voice.—I turn now to the pitch of individual vicarious sounds and the melody of vicarious conversational speech. One would naturally expect that the different substitutive mechanisms of speech would give great divergencies of pitch, but in general the observable variations of pitch are very slight. This is easily explained. Under normal conditions the pitch of a vocal tone depends on three factors: (1) breath pressure (the force with which the breath is "blown" through the glottis), (2) the length of the vocal cords and (3) the tension of the vocal cords. It is obvious that the laryngectomized patient has, at the most, but little power to influence these factors. The average range of a normal voice is about two octaves; it covers about twenty-four half-tone sequences. The vicarious vocal mechanism commands many fewer. Certainly, the second factor, changing the length of the vicarious cords, is practically out of the question. There remain the intensity of breath pressure and change in tension of the vocal cords. Wherever the vicarious air chamber may be, there is little possibility that its gaseous content can be moved with varying pressures and in varying amounts. Cases do, however, occur in which there is marked ability to vary pitch by increasing or diminishing the

49. Dahmann, H.: Ztschr. f. Hals-, Nasen- u. Ohrenh. **7**:329, 1924.

force of the mechanism which controls the propulsion of breath current. The chink in the pseudoglottis can be responsive to such action. Strübing [86] held that the elements composing the pseudoglottis are incapable of changing tension. It is true that a direct voluntary change of tension is hardly possible, but tension is influenced indirectly by movements of the head and neck. Indeed, this power is employed in vocal gymnastic therapy, being in many cases the basis of improvement not only in the clarity of the pseudovoice but also in its modulation. Stern's figures indicate that the intensity of breath pressure in the laryngectomized person can vary but little and therefore can hardly influence pitch and hence modulation. The figures reveal also, however, that movements of the head and neck produce changes in tension of the pseudoglottis of a fair range of variability and that in patients who learn to make these movements, modulation improves steadily. Stern believes such patients may attain a vocal range of two octaves, if they exercise and practice systematically. Practice is most important, and patients should be exhorted, even after they have mastered the new way of speaking, to continue practicing in order to bring their modulation as near perfection as possible.

In the light of the foregoing statements one is suspicious of the supposed infallibility of Müller's [50] "law of compensation of physical force in the vocal organ." The record makes this law conditional only, not so much in regard to the relationship between length and tension of the vocal cords as to that between the degree of breath pressure (intensity of breath current) and the pitch of the tone produced. An intensified breath pressure seems to exercise only an indirect influence on the pitch heightened by increase of tension. Manifestly, the relationship between pitch and the intensity of breath current does not hold for all cases. In my opinion, Müller's law of compensation governs situations conditionally. Further research should uncover experimental data for the modification of this law, which is held dogmatically, although it fails to apply under the conditions indicated.

Scripture [51] reported a case in which the vocal range was a full octave. The patient, a 17 year old girl, was able to form all the vowels at each pitch of that octave. Her larynx had been completely occluded, and she had breathed through a tracheotomy cannula for a period of three years. Her pseudoglottis was formed between the base of the tongue and the posterior margin of the palate. By means of a laryngeal

50. Müller, Johann, in Hölscher, J.: Handbuch der Physiologie des Menschen, Coblenz, 1840; Ueber die Kompensation der physischen Kräfte am menschlichen Stimmorgan mit Bemerkungen über die Stimme der Säugetiere, in Hirschwald, A.: Vögel und Amphibien, Berlin, 1839.

51. Scripture, E. W.: Speech Without Using the Larynx, J. Physiol. **50**:399, 1916.

capsule tambour change in pitch could be depicted by change in tension of the pseudoglottis. The consonants were as well formed on each pitch as the vowels, vocalization being absent only at the mediae.

A patient of Schilling [25] had complete stenosis of the larynx, which had been caused by diphtheria. This necessitated cannular breathing through a tracheostomy opening. At examination the condition was of three years' standing. The larynx had been twisted out of position by the formation of a cicatrix running in a diagonal direction from the right side behind and below to the left side in front and above. The patient nevertheless commanded a good singing and speaking voice at the time of examination. Pneumographic records showed that the phonic expiratory phase was often marked by a long expiratory standstill. (Schilling interpreted the condition as a mode of avoiding the adventitious noise caused by the cannula during respiration.) The pharyngeal air chamber was seen to correspond spatially with the mesopharynx and hypopharynx. The chief muscles affecting the diminution of this cavity during the act of speech were presumably the constrictor of the pharynx and the elevators of the hyoid bone, namely, the stylohyoid muscle and the posterior belly of the digastric muscle. The pseudoglottis was peculiar in being formed by an impact of the base of the tongue with the soft palate, much as cushions in the so-called *contrecoup* pipe come together.[51a] In particular, the participation of the tongue made possible a fine regulative control of the tension in the pseudoglottis, thus affording a wide vocal range with ability for good modulation. But because the tongue was engaged, clarity of pronunciation was naturally impaired, especially when involving the third zone of articulation. Yet, although a graphic record showed the renewal of air after each syllable, the syllabic sequences were confluent to the ear. Analysis of clang showed continual change in the length of the period (constant change in the pitch of the fundamental), as well as constant modification of the period's structure, accompanied by change in the character of the vowel. (A control period showed an approximate constancy in periodic length and structure throughout the entire duration of the vowel.) The periods representing the voice of the patient evinced true vowel character only at the beginning and at the end of pronunciation. The interval between showed only sinus vibration. Nevertheless, the character of the vowel was distinct to the ear. Nadoleczny [52] believed that in a case like this formants independent of the pitch of the fundamental, which was shown to rise rapidly, remain present.

51a. Kallen, Leo A.: Laryngostrobscopy in the Practice of Otolaryngology, Arch. Otolaryng. **16**:804 (Dec.) 1932.

52. Nadoleczny, Max: Physiologie der Stimme und Sprache, in Denker, A., and Kahler, O.: Handbuch der Hals-, Nasen- Ohrenheilkunde, Berlin, Julius Springer, 1925, vol. 1, p. 621.

COEXISTING NORMAL AND VICARIOUS MECHANISMS

A patient whose larynx is out of commission some of the time rarely has a substitute way of vocalizing that he can resort to even when the normal voice returns. Marx [53] reports one such case. A patient, 24 years of age, had suffered from cicatricial stenosis of the subglottic region as the result of an accident. Habitual drinking of beer had made him a remarkable belcher. When he was deprived of his voice, he found accidentally that he could make effective use of the capacity to belch for the purpose of speaking. When his more or less normal voice was restored by operative measures and therapy (laryngofissure and bougienage), he continued to use the vicarious mechanism, even though the normal one was available, speaking now with one, now with the other.

Schilling described a patient whose larynx was accidentally crushed. Treatment brought back the organ's respiratory function, but, although the larynx permitted the passage of air, it could scarcely function for the production of voice. During nonphonic respiration the intake and output of air occurred through the tracheostomy opening. During phonic expiration, though the air passed, in part, through the true glottis, it failed to produce voice. That came via a vicarious glottis formed between the base of the tongue and the posterior pharyngeal wall. To the air in the lungs there had been added an accessory air chamber within the esophagus. After each syllable spoken this accessory reservoir was continuously refilled with air by inspiration. Under fluoroscopy this process was observed as an oscillatory movement. If the tracheostomy opening was shut off, the true glottis could be made to function, but produced only a weak, hoarse sound. The patient preferred the vicarious mechanism to the normal one.

VARIATIONS IN VOCAL MECHANISMS

Evidently larynxless vocal mechanisms vary considerably, and the variations can be covered by no single generalization. One cannot say with certainty that, because the vicarious air chamber occurs in this or that portion of the upper alimentary tract or because the propulsion of air is effected in this or that way, the vicarious glottis must necessarily develop in a prescribed and definitive manner. Neither the location of the air chamber and the manner in which it works nor the location of the pseudoglottis and the manner in which that works can be foretold in every case. All that one knows is that the pseudoglottis, if a pseudoglottis happens to develop, must exist somewhere above the level of the air chamber. But it is established that these two vicarious structures

53. Marx: Patient mit Pharynx- und Larynxstimme, Med. Klin. **22**:1127, 1926.

occur now at the extreme respective ends of the upper alimentary tract, now in contiguity and now in interspatial relation with each other elsewhere in the tract. Dissociation is usual, but, as has been seen, by no means invariable. Indeed, various combinations remain essentially constant from the beginning, even under the influence of any method of vocal gymnastic therapy.

I believe, therefore, that the esophageal type of speech is the one to be striven for because of anatomic and phonetic reasons; but I recognize that it is not possible in all cases. The idiosyncrasies of the case qualify what is possible and what is not. The personal predisposition, the constitution, the habits of articulation before operation, the architecture of the articulation machine and, in particular, the postoperative anatomic results—all these are involved in the final decision as to procedure.

The term *pharyngeal* voice has invaded the literature extensively, owing to the fact that in many cases the pseudoglottis is lodged somewhere within the pharynx. Landois and Strübing [19] preferred the term *pseudovoice*. Since the mechanism of speech varies so greatly in laryngectomized subjects, a term is preferred which designates all the facts. Although *pseudovoice* does so for voice, it is inapplicable to the pseudowhisper. I propose, therefore, the term *alaryngeal* speech, which means speech without a larynx, regardless of the mechanism involved, and which logically includes the pseudowhisper.

THERAPEUTIC MEASURES FOR THE DEVELOPMENT OF A VICARIOUS VOICE

Basis of Technic.—I turn now to the pedagogic technic by which alaryngeal voice and speech are developed. This technic depends on two processes: the deglutition of air (aerophagia) or the aspiration of air into the stomach.

As to aerophagia, it is well known that speaking and eating are accompanied by the aspiration of air into the pharynx and even into the esophagus. The aspiration occurs with inspiration of the breath. It often happens that persons who speak in a rapid and explosive manner absorb more air than others. This they regurgitate reflexly, with ructus as a consequence. A rapid eater also swallows much air, and exhibits similar reactions, expelling the excess air from the stomach in the form of a belch. In both, eructation is a reflex, producing a specific sort of sound. The term implies a total complex consisting of aspirating air into the esophagus or swallowing it into the stomach, expelling it at once or later, either reflexly or intentionally, and producing thereby a characteristic sound.

Intentional expulsion of the air calls for a *learned* series of movements. The movements, learned or unlearned, are means by which to

produce sounds that can be articulated into speech. Making them is to practice air-eating, or aerophagia, which consists in drawing air into the upper alimentary tract and then eructing it. Eructation may consist in the escape of air just swallowed through the still open cardia or in its expulsion in quick salvo-like sounds from the stomach, where it has been intentionally accumulated.

Ordinarily, the cardia is closed off from the esophagus during the act of phonation. Not so in the case of aerophagia. Opening the cardia is a reflex act, initiated in the mucous membrane of the esophagus and coursing over the central nervous system by way of a branch of the vagus. Mikulicz [22] believes that the act of opening is due to an increase in intra-esophageal pressure. Others hold that it is caused by a reflex decrease in the tonus of the cardia following stimulation of the mucous membrane. Hacker and Sauerbruch gave great weight to the crus of the diaphragm, while their opponents declared that if the crus were as important as these investigators believed, the act of inspiration would make for a very feeble closure of the cardia. Gubarow suggested the occurrence of a valvelike occlusion due to the oblique insertion of the esophagus.

Some consider the chief effect as due to the intrinsic tonus of the cardia itself. Obviously, agreement on the matter is still lacking. Among internists, however, there is a consensus that the ever-recurring contraction of the cardia has its origin in the reciprocal relation between the involved forces of stimulation and inhibition.

When the gastric air bubble functions as a reservoir for air, there goes with the voluntary act of swallowing in order to accumulate air in the stomach an ever-increasing intra-esophageal pressure, which, on reaching a certain intensity, opens the cardia. When this is the situation the closure between the esophagus and the stomach is released during speech. This is the exact opposite of what occurs under normal conditions.

The Vocal Gymnastic Program.—A program of vocal gymnastics is not built on hard and fast rules. The procedure, though following a general plan, depends for details of treatment entirely on the idiosyncrasy of the individual patient. No single vowel or consonant, no particular articulatory combination serves as an indispensable point of orientation or a basis of construction. Intelligence, adaptability, skill and other qualities of character, together with the patient's bodily state, all enter into the determination of the program of vocal reeducation. Often some time elapses before the sound easiest for a patient to make is discovered and before it is evident whether aspiration or deglutition of air is more economical and effective. Hence, the first step in planning the development of vicarious voice in a patient is to bring together in

a single formula the characteristic common to the great majority of cases. The patient should be given the clearest possible idea of what he is trying to do and how it is to be done. What he is told will vary with his background and intelligence, but in no instance is it entirely impossible to be simple and explicit, if one takes pains. The importance of respiration in the development of normal voice becomes negative under the new conditions caused by the removal of the larynx. It is not only useless, but directly hinders the vicarious mechanism and causes rapid fatigue. It is the first obstacle for the patient to overcome. This is not easy. A central activity controlling the entire phonic complex continues to function, even though the lungs no longer serve the act of phonation.

Reconditioning of Phonic Respiration: The patient's first task, then, is to learn to dissociate behavior patterns of a lifetime. This is taught to different persons in different ways. For one patient the best results may be secured by teaching him to hold the thorax in the position which follows inspiration and so to swallow or aspirate air. For another the best results may follow when deglutition or aspiration takes place after the lungs have been emptied of breath. Either way will serve. The act may be easier, as Hopmann [54] thinks, with the chest in the position that it has when the lungs are empty. If the palms of the patient are laid on either side of his chest, he learns through the feel how to control and regulate the process consciously. This is the first step in the development of a vicarious vocal mechanism, and it must be persisted in diligently until the control is perfect. So far as possible, sudden expulsion of aspirated or swallowed air is to be prevented. The air should pass from the stomach or esophagus in a steady, continuous stream of the same intensity throughout, under the pressure of the esophageal and thoracic musculature. It is this pressure which the hands register.

Production of Sounds and Syllables: This exercise is supplemented by the use of the oral cavity as an air chamber. This is carried out by repetition of the nonvocal explosive sounds P, T and K, abdominal or thoracic movements being prevented while the sounds are made. At first the sounds will be hardly audible. To give the patient an objective measure of his progress, fine strips of paper may be held in front of his mouth; their increasing motion will indicate the improvement in the force of the expiratory puffs. A more accurate method is to connect with a mouthpiece and tambour and make a graphic record. As the patient improves, he is to be taught to combine these sounds with a sequence of vowels: pa (pah), pe (pay), pi (pee), po, pu (poo); ta, te, ti, to, tu; ka, ke, ki, ko, ku; etc. Then he is to repeat the same

54. Hopmann: Stimm und Sprachübungen nach Kehlkopfausrottung, Deutsche Ztschr. f. Chir. **99**:301, 1909.

syllable a number of times in as many breaths. Finally, he is led to attempt to execute this syllable and a sequence of syllables in one and the same breath. Patients who are being taught to use the deglutition and not the aspiration mechanism may gain by making as noiselessly as possible movements of sipping, swallowing, sucking and otherwise using the lips, jaws and tongue. The production of the sound immediately after the movement of swallowing is especially helpful in the formation of a pseudoglottis.

Possible Untoward Effects During the Learning of Aerophagia: In this connection there arises the question of the harm which may come to the patient from a method depending on eructation and on enlargement of the gastric air bubble. The learned physiologic aerophagia is similar to an unlearned pathologic one. The latter is often accompanied by cardiac and respiratory distress. It is true that a small percentage of patients who are being taught to use vicarious voice mechanisms complain of difficulty in breathing, tachycardia, etc., while they are learning to dissociate voice from respiration. But symptoms of a threatening nature are hardly ever found.[55] I have not seen any in my own practice. But since a danger, however remote, exists, the therapy should be carried on with the greatest care. Overpractice, especially, should be forbidden. Often after hearing themselves make their first intelligible phonations, patients become overzealous and try to talk to every one at all times. It is, under any circumstances, wisest rigidly to prescribe the length and the character of the exercises until dissociation is perfect, and to permit the patient no choice. Cases occur in which air is swallowed with such powerful movements that great effort is required to reduce them. A useful device is to place a medium-sized stopper or a similar article between the teeth.

That the therapy so rarely produces harmful sequelae may follow from the fact that the reciprocity of stimulating or tonicizing and inhibiting or relaxing agents conditions the ever-recurring contraction of the cardia. Stimulation occurs in the cardia itself; inhibition comes via an efferent reflex set up by an increment of intra-esophageal pressure in the mucous membrane of the esophagus. The laryngectomized subject manipulates swallowed air so as to expel it at once and thus easily to open the closed cardia, whereas the pathologic aerophagist shows a delayed reaction, accumulating a considerable quantity of air before expelling it. The air which the laryngectomized person swallows is at once employed for phonation; it cannot accumulate in disturbing quantity in the esophagus or stomach, regardless of how it originated. In many cases it does not stay in the stomach, but, as has been seen, migrates

55. Stern mentioned two cases in one hundred; other investigators, none.

to the esophagus. Hence there is not the same damage to the stomach as in neuropathic aerophagia.

Aids in Production of the Ructus: Patients who find eructation difficult should be given carbonated water to ingest during the practice periods. They belch, and as the belching is produced it is articulated into some vocular value, such as ka (kah), go, etc. In some cases swallowing and eructation are facilitated by protracting the tongue. In other cases pretending to drink out of a glass greatly helps the accumulation of air through deglutition into the esophagus and stomach. I have often found it effective to have the patient close off the tracheal cannula after forced expiration, since immediately thereafter the diaphragm and the walls of the thorax execute inspiratory movements. The marked negative pressure thus produced within the thoracic cavity facilitates the entry into the esophagus of air swallowed while the mouth is held open. Monosyllabic words, such as gut, got, cut, Kate, etc., are to be preferred. The posture for articulation required by the specific sound to be made must be assumed beforehand. From this process, when it is carefully practiced and controlled, the patient gets an excellent idea of the nature of the pseudovoice at the beginning of the therapy. The method serves to carry the patient over one of the high hurdles of the therapy, and thus shortens the treatment; but, most of all, it greatly facilitates the production of fluency of the vicarious voice itself.

Priority of Articulations and Articulatory Combinations to Be Practiced: The question as to which articulations are to be practiced first and which later is a matter of judgment. Experience, however, seems to favor the use of the fricative hums V, Z, etc., as soon as practicable. Also, the early use of the nonvocal fricative F, Sh and S appears to be advantageous, as producing them by narrowing the apparatus for articulation intensifies the compression of breath behind them and so strengthens the vicarious mechanism. These sounds may be followed by words containing the explosives, such as got, gut, good, git, kit, kiss, kissed, coo-coo, cook, etc. When working with words of two or three syllables, the patient should be taught to pronounce the first syllables rapidly and to stress the last one. By such practice he is prepared to pronounce polysyllabic words with full voice and articulation. Great difficulty is encountered in pronouncing the double consonants. They use up more air than the others, and require differentiation between the aspirate and hard types of intonation. Fortunately, not much time need be given to those combinations, as their inaccuracies exercise little influence on the comprehensibility of speech in the beginning, and in the end the patient masters them. The important thing is to see to the proper establishment of dissociation between vital respiration and the new phonic "expulsatory" activity and to the latter's economy. Dissociation may be facilitated by reenforcing the deglutition of air with

the thorax in the position of inspiration or expiration by closing the tracheostomy opening. This not only obviates adventitious sounds and immobilizes the thoracic walls but makes for greater clarity. The effectiveness of this device becomes more noticeable when the patient is able to speak short sentences and, in general, to undertake conversation. Words beginning with explosive sounds greatly facilitate learning. Such words are kit, kissed, doft, ten, gat, cast, cocoa, etc. They are more easily produced than words beginning with vowels, because the closure required to utter the initial consonant calls for a certain degree of compression of the breath, which must also be sufficient to activate the pseudoglottis. As the intensity of the initial explosion increases, a sharp friction sound in the resonating pharyngeal cavity becomes more and more noticeable. This, however, is not to be identified with the friction sound occurring between the tongue and the palate; it originates lower down in the hypopharynx. The explosive value K is well suited for this purpose. Sometimes the pharyngeal friction sound referred to first appears when the K is combined with some vocular value, especially O, OO or OI. Any syllabic value which is noticeably associated with this sound should be combined with other values with which it is not associated, in an effort to carry it over. Some investigators, notably Gutzmann,[23b] believe that this pharyngeal friction sound is the embryo of the pharyngeal voice. The word kit, beginning and ending with an explosive sound, is useful here. After the word has been mastered, the various vowels and diphthongs are combined with it. Thus: kit-aaaaaaaaaaaaaaaah, kit-aaaaaaaaaaaaaaaay, kit-eeeeeeeeeeeeeeee, kit-oooooooooooooo, kit-uuuuuuuuuuuuuuu, etc. Every effort should be made to avoid admixture of disturbing adventitious sounds. Such sounds may be due to overexertion by the production of too much force, respiratory movement with the production of breath sounds, a too hasty tempo of speech, etc.

Reading Exercises: Success in speaking short sentences should be followed by practice in reading. The patient should be directed to read as fast and fluently as he can. No special pains should be taken to correct any difficulty encountered during the reading. The patient should be instructed simply to pass it by. Repetition of the exercise will show constant improvement. Reading should be executed without any break in the phonic stream, hence no stopping for mistakes. Observation of how, with practice, the patient improves in reading, makes clear that the relationship between vital respiration and the new phonic activity gradually regulates itself. The final stage is reached when the new process is established as an automatic behavior pattern. This is speeded up if the patient practices the exercises in all positions—standing, sitting, walking about, lying down, etc., so that the new manner of speech may become adapted to as many postures of the body as possible.

Modulation Exercises: To cultivate modulation the patient should be taught "singing." By this means he may be enabled to sustain tones within the range of an octave beginning somewhere between E and A. Certain postures of the head associated with definite tension effects in the mesopharynx and hypopharynx will help here. In time, most patients learn to differentiate intervals within a major third or perfect fourth. Musical patients may even learn to produce tones limited by the interval of an octave. Stern [24c] reported a case in which two octaves were mastered, namely, E-e-e'. This is a few tones better than in Gottstein's famous case. Singing exercises have a favorable influence on the general character of the pseudovoice, which becomes more and more like the normal voice of a person with chronic laryngitis. In some cases the raucous clang is hardly noticeable, and even though the voice is low in pitch, it has considerable intensity, clarity and modulation. Before the meeting of the Trilogical Society in St. Louis in June 1931, Morrison [56] demonstrated a vicarious voice which had been recorded on a phonographic record. The reproduced voice could be heard and understood distinctly throughout a large hall.

Aids in the Development of the Pseudoglottis.—Sometimes movements of the head facilitate the production of a succession of syllables because they speed up eructation. Different cases call for different movements. Sometimes nodding movements are more effective; at other times bending the head forward on the chest or movements of the head from left to right and vice versa gives better results. The tensions of these movements contribute to the formation of the pseudoglottis. Pressure on the soft parts in the region of the angle of the jaw or backward at the base of the tongue also helps to develop the pseudoglottis. The exercises which I employ in phonetic therapy for unilateral paralysis of the recurrent laryngeal nerve are often useful to influence the tension attributes of the pseudoglottis and other coordinated factors of the new speech mechanism.

Question of Relapse.—It is necessary for the therapist always to bear in mind that in order to establish a new type of ideation it is necessary to adapt and establish as habit a new set of muscular coordinations. The possibility of relapse should be borne in mind. This sometimes occurs during the course of therapy and appears to be like a crisis, but is not one. Suddenly the patient may seem unable to produce any sound, perhaps for a few hours or a few days. The cause is usually psychic and somatic indisposition following overexertion, the excess tension of the muscles producing a sort of paresis. Occasionally there is slight gastric atonia. This soon disappears with the other disorders. The

56. Morrison, W. W.: Production of Voice and Speech Following Total Laryngectomy, Arch. Otolaryng. **14**:413 (Oct.) 1931.

patient should be told in the beginning that such things may happen. As a rule, five or six ten minute periods of practice throughout the day seem sufficient for patients, but the period and interval must be suited to individual need. The best possible practice consists of conversation, which should begin as early as possible. But even when conversation becomes fairly facile, the routine of specially designed exercises should be systematically kept up.

Vocal Methods Other Than Deglutition.—The Aspiration Method: So far I have considered only the air-swallowing mechanism and its relation to the pharyngeal voice. The esophageal mechanism requires the training of muscles the movements of which make the mechanism possible. For this purpose, phonation exercises carried out with the thorax in the inspiratory position are best, for they allow a better play of the esophageal phonation contractions. The patient is taught how to aspirate air into the esophagus and then expel it so as to produce sound. The movements should be only those absolutely necessary to accomplish this end; all movements that tend to occur concomitantly must be eliminated. With proper instruction, this does not take long to learn. The relative advantages of esophageal and pharyngeal mechanisms have already been discussed and need no further elaboration. Suffice it to say that the chief opponent of esophageal voice, Stern, objects mainly to the aspiratory sound, which he believes is unpleasant.[57] Seemann, who favors the esophageal voice on grounds of physiology and anatomy has, in my opinion, the wiser view.

The "Sigmatismus Nasalis" Method: A method suggested by Fröschels,[57a] to the success of which I am able to testify from observation, is to make the patient conscious of the sound produced between the posterior pharyngeal wall and the soft palate. The patient is carefully instructed as to where the sound is to be made by means of the pathologic mechanism of the so-called "sigmatismus nasalis." This mechanism produces all the sounds of the sigma series through the nose, instead of through a particular narrow portion of the second zone of articulation, as is normal. A person having this particular defect in articulation but otherwise speaking normally produces a peculiar friction sound between the soft palate and the posterior wall of the pharynx as he sends the breath intended for the sibilant sound out through the nose. In some cases this sound can be brought to the patient's consciousness and used as a control of the muscles that must necessarily be brought into play.

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57. The aspiratory sound itself, as Fröschel's case [42b] and my own case (Arch. Otolaryng. **15**:478 [March] 1932) prove, can, on the contrary, be made to serve the purpose of fluency and thus constitutes a distinct advantage, apart from our preferring it on physiologic grounds.

57a. See Stern.[34a]

PROGNOSIS IN VOCAL THERAPY

In no other field of vocal pathology is the vocal prognosis so completely favorable as in the laryngectomized patient. Other things being equal, much depends on the patient's psyche. He starts with any number of resistances, which must be overcome. Often he resents the belch-like character of his speech, and even after he has become fairly fluent he is ashamed to speak in the presence of strangers. This feeling stops the mechanism, the pharyngo-esophageal tube undergoing spastic closure which completely shuts out any sort of sound production, even by patients who at other times show fine control. This inhibition the patient himself must overcome. His hypersensitiveness and easily disturbed emotional balance must always be borne in mind and handled with the utmost care. Mental depression alone can seriously interfere with the patient's progress. A not unimportant factor in the prognosis is the patient's manner of speech and articulation before the laryngectomy. Apart from consideration of his age and training, if his speech was clear and well enunciated before the larynx was removed, he is more apt to cultivate a clear and well defined pseudospeech.

It has been seen that spontaneous development of voice and speech in laryngectomized subjects is not uncommon. When skill and adaptability are added to a favorable anatomic condition a patient may cultivate voice and speech merely by practicing conversation, etc. He would, however, suffer from not having learned how properly to dissociate his new method of talking from the normal movements of respiration. These movements, occurring simultaneously with the deglutition of air, cause adventitious sounds that interfere greatly with the new sound intended for articulation. Nevertheless, in many cases spontaneous speaking progresses to successful articulation. In other cases the patient fails, in spite of all vocal therapy. The latter are not many, however.[58] The danger that the mechanism of the pseudowhisper may develop before vocal gymnastics can be applied has already been referred to. Not infrequently it is the appearance of the pseudowhisper that accounts for such occasional vocal failures as do occur. It is a risky habit, even though there are patients who have achieved very good voice and speech through vocal gymnastics which were not begun until three and four years after the operation. Sometimes a gastric pathologic condition rendering eructation impossible interferes with the development of the vicarious voice.

58. In the one hundred and more cases which he guided phonetically, Stern found only two in which the voice could not be brought beyond the pseudowhisper. His statistics show that 5 per cent of all cases of total extirpation at the Hajek clinic were in women. In general, this 5 per cent seem to have done much better than the 95 per cent of males who learned to use vicarious vocal mechanisms. Whether this is significant cannot be determined until further statistical evidence becomes available.

Other causes are general debility and senility. Inability to understand the mechanism involved considerably lengthens the time of treatment, even if the patient perseveres. In general, age does not affect learning the new way of speaking.

The wound caused by total extirpation heals completely within about six weeks. Phonetic therapy should be inaugurated immediately after healing, even though, as in some cases, primary healing has taken only three weeks. The sooner vocal gymnastics are started after healing the better. As a rule, the patient, eager to get home, leaves the hospital at the earliest possible moment and even if he wishes to stay on, the hospital lacks a phonetic department, and he must necessarily leave without post-surgical phonetic treatment. This is especially regrettable. He leaves the hospital with a handicap that cripples his life. His loss of speech leads to maladjustments, depression and lowered resistance which, some believe, can cause a recurrence of the disease, which may otherwise remain latent. As a rule, the patient who goes about hale and hearty years after the operation has learned to use a vicarious speech mechanism and has been enabled to continue in his profession. Many cases have come under my observation in which the mastery of a vicarious voice has been followed by a complete change in personality and the recovery of bodily health. This change is not likely when a mechanical device is used. A mechanical device does not replace an inherent biologic function. It does not become an integral part of the patient's psyche. It remains at best a useful machine never entirely identified with his personality.

It is toward the ends described and toward a happy readjustment to as normal a life as possible that the aim of all vocal gymnastic therapy in the laryngectomized patient is directed.

A METHOD OF SPECIFIC TREATMENT IN CERTAIN STREPTOCOCCIC INFECTIONS

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For many years blood transfusion has been a favorite method of treatment in severe complications following otitic and mastoid infections and has likewise been used by physicians generally in a variety of other diseases. In a small percentage of cases the benefit derived from the procedure has seemed to be out of all proportion to the replacement value of the blood elements introduced and has, I believe, been generally attributed to the presence of specific immune bodies in the donor's blood.

With this idea in view I have endeavored in the past to secure blood for transfusion from donors in whom immune bodies specific for the patient's disease might be assumed to be present. This assumption could reasonably be made when it was known that the donor had recently suffered from the same or from a similar disease caused by an identical organism, so far as could be determined, and preferably when it could further be reasonably assumed that the disease had been communicated from the original sufferer to the patient.

Excellent results, obtained in a few cases by this method, served to convince me that much good could be accomplished if it were possible to have the necessary donor or the specific serum available when the need arose. This was, of course, the difficulty, for only occasionally could such a fortunate chain of circumstances be expected to exist. Consequently, I was forced to cast about for some more dependable source of supply—some method whereby it was possible to have on hand at all times specific serums, and some further method whereby the proper serum could be selected for use in a given case.

As a result of this effort and through a process of trial and error, two factors have been worked out which promise to increase greatly the scope of usefulness of human immune serum. It is already well known that many serums are specific for the diseases from which they originate. In fact, prophylaxis and, to some extent, treatment with convalescent serums in diseases such as mumps, measles, chickenpox,

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whooping cough and scarlet fever is well established [1] and widely used, but I have not seen the fact mentioned in the literature that certain serums contain immune bodies which are specific for diseases other than those following which they have been obtained. This, I believe, is now clearly established, and it is the first of the aforementioned factors. The second factor is the development of a practical method for determining specificity as a preliminary to treatment. These two factors have been combined and elaborated to form a method of treatment, and the organisms against which the method was first successfully tried were the streptococci, the most common and frequently most deadly offenders. Accordingly, this study constitutes a preliminary report on a method of specific treatment of streptococcic infections. The work has not yet proceeded far enough to enable me to say how many varieties of streptococcic infection are amenable to this form of treatment. Many undoubtedly are not, but the results of this work prove to my own satisfaction, at least, that many are, and I am able to point to a modest series of cases in which a prompt cure appeared to have been obtained by the means to be described.

SOURCES OF SERUM

In my search for specific serum I have systematically proceeded to take blood from every patient convalescing from acute streptococcic infection, of whatever type, with whom I have come in contact or whom I have been able to follow by any means available. Thus far, patients convalescing from scarlet fever and from streptococcic infection of the throat have proved to be the most fertile and satisfactory sources of supply, especially the former. Strangely, erysipelas serum has thus far proved of little value, but no type of known streptococcic infection is ignored, and even serums from diseases of unknown etiology, such as measles, are being experimented with as a routine. The blood is drawn into a sterile container, usually up to 500 cc. at one sitting, and is taken at any time during the convalescent or postconvalescent period after the patient has been afebrile for at least one week and all suppurative lesions are healed. Theoretically, the number of immune bodies rapidly decreases after a certain time, and for that reason it is desirable to secure the blood as early as possible. However, immune blood is cer-

1. Gordon, J. E.: Convalescent Serum in Control of Communicable Diseases, Illinois Health Quart., Jan.-March 1932, p. 53. Cowley, R. H.: The Treatment of Measles by Immune Serum, Therap. Gaz. **1**:387 (June 15) 1926. Gordon, J. E., and Meader, F. M.: The Period of Infectivity and Serum Prevention of Chickenpox, J. A. M. A. **93**:2013 (Dec. 28) 1929. Meader, F. M.: Scarlet Fever Prophylaxis, ibid. **94**:622 (March 1) 1930. Park, W. H., and Freeman, Rowland G., Jr.: The Prophylactic Use of Measles Convalescent Serum, ibid. **87**:556 (Aug. 21) 1926.

tainly valuable at any time within from four to eight weeks after recovery and in some instances for a much longer period.

At the time the blood is taken a sufficient amount for serologic tests is set aside and a Kahn or Wassermann test is performed as a routine. When the results are positive, the blood is discarded, although it is likely that most samples of blood giving positive reactions are free from viable spirochetes and it is by no means certain that those giving a negative reaction are necessarily safe. Therefore, in addition to serologic tests it is even more important to exclude by physical examination and history the presence of a syphilitic infection, and serum filtration should be used as an added safeguard.

The flask of blood is then placed in the refrigerator overnight. After coagulation is complete the serum is separated by centrifugation, passed through a Seitz filter and cultured; if it is sterile, a 0.3 per cent solution of cresol U. S. P. is added, and the serum is placed in sterile ampules containing 5, 10 and 20 cc. each. For perfect assurance of safety, these ampules are incubated for one week, cultured again and then sealed. The ampules may be all glass and sealed in flame, but if the serum is to be used within a reasonable time, it is practical to put it up in rubber-stoppered vaccine vials and to dip the upper portion in collodion for perfect sealing. In any case, it is desirable to put up one sample 5 cc. vial in this manner so that a sterile needle may be introduced through the stopper at various times and small amounts of serum withdrawn for testing as to specificity.

DETERMINATION OF SPECIFICITY

The determination of specificity is done quite simply. A culture of the blood of the patient to be treated is carefully taken, preferably by the physician in charge. This important detail should not be left to the laboratory. Technicians are not familiar with anatomic regions, and if, for example, a culture from the throat is desired one should make sure that it comes from the lesion and not from the mouth. The culture is made, preferably, on a blood agar plate and incubated for twenty-four hours. At the end of that time, or possibly sooner, sufficient growth will be present to identify the organism; it should then be ascertained whether or not specific serums are available.

The sample 5 cc. vials are now brought into use, and agglutination tests are made on the organisms from the culture with serum from each available sample, undiluted serum being used. The speed and completeness with which agglutination takes place seem to be significant, an agglutination which is complete in three minutes, for example, being highly positive, but from fifteen to thirty minutes should be allowed to elapse before the results of the test are considered entirely negative. Not infrequently agglutination will be found to be immediate and com-

plete, and in such instances experience seems to indicate that it can be confidently predicted that that particular serum will be specific for the infection from which the patient is suffering. If one or more samples are positive but none gives immediate and complete agglutination, the one reacting most completely and in the shortest time is selected. Clinical results may be expected to be proportionately variable, modified also, of course, by the gravity and extent of the disease and the resistance of the patient. If none of the samples of serum agglutinates the organisms, or if agglutination is very slow or strikingly incomplete, there is, so far as I now know, little to be expected from treatment along this line—the case is probably not one to benefit by specific treatment.

At this point it is appropriate to call attention to certain interesting and significant facts. In performing the agglutination tests it will be found that similar serums do not necessarily all agglutinate a certain organism. For example, tests with several different scarlet fever serums may be made—one may agglutinate the organisms, and the others may not. Or one scarlet fever serum and one serum from a streptococcic infection of the throat among two groups of each may do so, and the others may not. When this is true, experience indicates that it is useless to attempt treatment with any but the serum which agglutinates. It is not a case of any scarlet fever serum proving efficacious if one does—each should be tested for its own specific properties against a given organism in every instance.

Another important observation has been that specificity does not seem to be safely predictable by empirical means, especially if the prediction is based on the type of organism causing the disease from which the donor was convalescing. For example, the donor may have recently recovered from scarlet fever caused by a particular type of hemolytic streptococcus, but this does not mean that his serum will prove antagonistic to all hemolytic streptococci or to hemolytic streptococci only. It may be highly active against other forms of the organism, such as Streptococcus viridans, against several nonhemolytic strains or against none at all. These observations are not easily explained, and when one considers the added mystery of each donor's background, with his various acquired and inherited immunities, the subject becomes even more confusing, and some of the reactions are still less easily accounted for.

However, for the present purpose, it seems justifiable to conclude that one does not need to have in stock serums which have been produced by the protective action of the body against each and every variety of streptococcus. The great number of strains of streptococci precludes the possibility of such a thing, and these observations indicate that serums from many donors are protective against greatly different clinical manifestations and against a variety of different strains of the organism.

This seems to be true regardless of the disease which produces the immunity, and serums from different persons who have had the same disease will be found, in many instances, to be specific for different infections. In fact, only rarely do all of them indicate specificity for the same infection, and almost never have they been found to be equally active in agglutinating power against organisms from any given case.

For example, it was found that of three scarlet fever serums tried in a serious case of cardio-arthritis, only one proved satisfactory—a result borne out by repeated agglutination tests. The least powerful serum was first used clinically, without result, and so on for the series, only the last and most actively agglutinating serum proving effective. In another case of fulminating streptococcic pharyngitis, laryngitis and sublingual and submaxillary cellulitis, two different serums were used simultaneously in the hope that at least one would prove to be specific pending the growth of cultures. As anticipated, one, a scarlet fever serum, gave prompt and complete agglutination, and improvement was immediate and gratifying. However, an attempt to further the improvement by means of another scarlet fever serum which gave a negative agglutination test was an obvious failure. Subsequent resumption of treatment by means of the known active serum first used was followed by prompt and complete recovery.

Such examples could be greatly multiplied, but for the present it is sufficient to conclude that positive agglutination seems to be the best indication of specificity. I have not yet encountered a case in which rapid, complete agglutination proved deceptive as to specificity when the serum was used in adequate dosage. But it should be emphasized that the method has not yet been applied in a sufficiently large series of cases to make blanket statements regarding it. I can only say that the results of agglutination tests are encouraging and will bear further critical study. On the other hand, it is possible that in certain instances serums which do not agglutinate may possess protective substances of value to the patient. Repeated trials have proved that in the main this is not true, but there may be exceptions. Generally, however, giving just any serum will prove extremely disappointing—the serum is either specific and acts accordingly, or it is entirely useless.

As a further test of specificity, the lytic power of the serum may be tried. Lysis may occasionally take place when agglutination does not. The test is more difficult, but still perfectly practical, the greatest objection to its use being that it is time-consuming and increases the delay. However, it is worth trying in the absence of successful agglutination tests, and if lysis occurs one has again a presumptive indication of specificity, but not always a dependable one.

Great care is essential in selecting colonies for agglutination tests when time does not permit subculturing. It is sometimes difficult to

differentiate accurately between streptococci and contaminating organisms while clumping is taking place, and the latter may agglutinate very readily with almost any serum. This is frequently the case with the ordinary contaminating staphylococci and could easily prove deceptive in a test hastily or carelessly performed. On the other hand, it is most frequently highly desirable to obtain positive laboratory results in the shortest possible time, and tedious technical methods are, therefore, precluded. After all, the object is to relieve the patient, and in many cases early administration of the serum is essential to that end.

It is evident that the results so far attained argue against the use of pooled serum, such as is used in measles and scarlet fever prophylaxis. While pooled serum may prove useful in certain cases, in this work it is infinitely better to keep the serums separate. To pool them merely dilutes the active serum with that which may be inactive in a given case, thus making it necessary to use larger doses for therapeutic effect, and consequently causing a waste of valuable serum.

TREATMENT

Before proceeding with the details of treatment by this method it should be mentioned that its use does not eliminate the need for sane and reasonable clinical management. It is, of course, logical and necessary to remove or drain the original focus of infection or localized collections of pus wherever possible. Such procedures are dictated by common sense.

The amount of serum used is variable and would be of no particular significance, so long as it is sufficient, were it not for the fact that these serums are usually precious and that, accordingly, one wishes to use the minimum dose which will secure the desired result. Experience indicates that individual serums vary in immune content and, as standardization is not practical, dosage is necessarily empirical. In critical cases it is my custom to use an introductory dose of from 20 to 40 cc. followed by a second dose of the same size in twenty-four hours if it seems necessary. In less urgent cases an initial dose of as little as 10 cc., repeated in twenty-four hours, has proved successful. However, it seems preferable to begin with a maximum dose and to withhold a second or a third injection for a few days if the improvement is marked. In this way, a maximum initial effect is secured and the necessity for further treatment may be avoided. Often it is important to administer the serum at the earliest possible moment. In fact, such early administration may be essential to the success of the treatment. A problem arises as to the best course to pursue in order to hasten results. Cultures take time, and time is precious. Therefore, in urgent cases, it is my custom to study direct smears for whatever value they may have, and then to administer empirically the serum which in my judgment

best fits the case. This is a highly speculative procedure, based on clinical experience with similar infections and with the various serums in my collection, but it is harmless, and in some instances has successfully bridged the gap between the time of first seeing the patient and the securing of results from cultures twenty-four hours later. At that time the described procedure can be completed and the patient more scientifically treated.

In a few cases a total dosage of as much as from 80 to 120 cc. has been used, but as a rule the maximum is from 40 to 60 cc. When the lesion is massive, and the disease well along in its progress and apparently firmly entrenched, or if for any other reason the infection appears extremely difficult to dislodge, it is preferable to resort to immune transfusion. This is accomplished by testing the agglutination reactions of a number of immune serum donors against the patient's organisms and using the best donor for transfusion. From 300 to 500 cc. may thus be administered, with the added advantage of whatever value the blood itself may possess. Blood matching is, of course, a necessary preliminary. When the patient is in need of blood, immune transfusion is a logical step and adds greatly to the value of the donation. It is not difficult to have on call a reasonable number of immune donors for this purpose, having made tentative arrangements with each at the time blood for serum was taken.

The serum is best given intramuscularly or intravenously; the latter method is preferable as the results are quicker and more positive. This is especially true in the early stages of exceedingly acute infections, but the increased effectiveness of the intravenous method and its freedom from local soreness make it most desirable wherever it can be used. Regardless of the method of administration, it seems obvious that no true serum reaction could result with human serum, although theoretically a possible allergic reaction could occur if the donor's serum happened to contain certain substances from his diet to which the recipient was sensitive. Practically, experience indicates that if the proper precautions are observed there is no harmful effect whatever from the serum; at least, none has been observed thus far.

RESULTS

Startling improvement is invariably noted in the second twenty-four hours if the serum is to be of any value to the recipient. In acute cases some improvement may even begin to show itself before that time, but seldom in less than twelve hours. There is a fall in temperature, with subsidence of swelling and soreness in soft tissues, and diminution in discharge, if any is present. Even in apparently desperate cases convalescence is rapid, often taking place within a week, with almost complete cessation of symptoms in the first four or five days,

sometimes with normal temperature in three days. Rapid improvement in the blood picture is also evident, along with an amelioration of general symptoms. If positive and definite improvement is not noted it is useless and wasteful to continue the administration of the serum.

The method has thus far been used with success in a variety of conditions, including streptococcic tonsillitis, tonsillo-adenitis, pharyngitis, laryngitis, cellulitis, otitis media, mastoiditis, sinusitis and cardio-arthritic disease. I have not yet applied it in a case of general sepsis because no satisfactory cases have so far been submitted for trial. In one such case no agglutination whatever was secured. Others have been either hopelessly late with extensive metastasis or, on the other hand, have shown improvement, with excellent chances of recovery without serum treatment. The method has been tried without success in two cases of streptococcic meningitis. However, neither case was favorable at the time of administration; one patient died in two hours; the other was obviously in a hopeless condition, having been ill for ten days, with almost pure pus in the spinal canal. I believe that the method has some chance of success in early meningitis, along with proper surgical treatment when the latter is indicated. All the remote conditions in the aforementioned series had their origin in acute tonsillar or pharyngeal infections.

GENERAL OBSERVATIONS

Up to the time of writing this work has not included a sufficient number of cases of other than streptococcic infections to make it possible to report results in such instances. A study of other infections is now in progress, but for the present it has seemed sufficient to offer what is in the nature of a preliminary report on the streptococcic serums only. Further, more detailed reports will be forthcoming as experience with the method accumulates.

There is, of course, no reason to limit this work to infections of the respiratory tract and their complications. Any form of streptococcic infection should be considered amenable to the same method of treatment until proved otherwise, and at the present writing I see no reason, when serums are found to be specific, why many forms of streptococcic infection should not offer the same hope of control.

It should be emphasized that the method is essentially clinical, and no effort has been made to identify the various strains of streptococci by complicated laboratory methods. Ordinary cultural characteristics are noted and recorded, but fine differentiations are not attempted. Although it is, no doubt, of academic and scientific value the knowledge gained by exhaustive bacteriologic studies in each individual case seems to me to promise little along practical lines. Also, extensive studies of the characteristics of innumerable strains of streptococci have already

been made by students who are infinitely better qualified to make them than I am.

If others take up this work they should not be discouraged by failure to find a specific serum for every case. Neither should relapses or even absolute failures in exceedingly serious cases be deterrents to further study of the method. Such disappointments are usually due to late administration, insufficient dosage or utterly overwhelming infections. After all, the patient must be able to do his part in recovery, or the method will fail. Even such a well proved specific agent as diphtheria antitoxin does not always succeed, and the diphtheria bacillus is not nearly as protean in its manifestations as the streptococcus. Neither is it as various as to strains and virulence. The serum is not intended to be a cure-all, and failures are sure to be encountered, but they can be minimized by securing and keeping on hand as large an assortment of serums and as large a list of immune donors as possible. At least ten different samples of serum should be always available for testing, and it is highly desirable to have many more than that when possible.

Many cases might be cited illustrative of results in this work, but, after all, the best evidence and truest test of the usefulness of the method must come at the hands of others. I hope it may be accorded that test, although it may be objected that the procedures involved are complicated, troublesome and not widely applicable because sufficient convalescent serum might not be always available and because all localities do not possess the necessary facilities. I realize that all these objections are valid, but I hope they will not prove to be conclusive arguments against trying a method which promises, in many instances, to save lives and alleviate suffering.

SUMMARY

1. Preliminary studies suggest that blood serums from patients convalescing from various streptococcic infections frequently contain immune substances antagonistic to similar but not necessarily identical organisms.

2. Specificity seems to be indicated by positive agglutination tests.

3. Moderate doses of such serums, properly checked for specificity, or blood transfusions from their donors, have proved highly effective in the treatment of many varieties of streptococcic infection.

4. Further tests of the method are in progress, in addition to a study of similar properties of serums from other, nonstreptococcic, infections.

510 Republic Building.

TREATMENT OF TRAUMATIC INJURIES TO THE NOSE

WITH SPECIAL REFERENCE TO AUTOMOBILE ACCIDENTS

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The universal acceptance of the automobile as a vehicle providing pleasure and as an indispensable means for conveying both passengers and freight has created problems, some of which had no practical significance a generation ago. While the number of new roads and thoroughfares has increased enormously and the perfection of construction apparently has been reached, the number of cars and the increased speed with which they are driven introduce risks that may be reduced by improvement in the construction of the machine and by increased skill on the part of the driver, but they can never be eliminated.

In automobile accidents an important consideration that frequently affects both the primary gravity of the situation and the results of surgical procedures is the isolation of the locality where the accident occurs and the unavoidable delay in securing proper surgical attention. In these mishaps the nose is injured more frequently than any other part of the body. This is due to the proximity of those in the front seat to the wind-shield, toward which they are thrown with violence when the speed of the car is suddenly arrested. The severity of the injury may vary from slight abrasions to maceration or amputation of the entire organ. If the nose has been completely severed from all vascular connections it will be lost, unless accurate, aseptic replacement can be effected at once. That it is possible, however, to restore the integrity of the organ after complete amputation is said to have been amply demonstrated many years ago in India, where it was customary to cut off the nose as a punishment for certain crimes. It was discovered that some of the culprits had recovered their severed organs and had succeeded so well in grafting them on that they had practically escaped the penalty for their crimes. The law had to be amended so as to include destruction of the amputated member.

One of my patients, a girl, 8 years of age, was injured when the car in which she was riding, in the front seat, collided with a truck. The broken glass of the wind-shield shaved off her nose almost on a level with her face. The accident happened several miles distant from the nearest hospital. In the excitement no thought was taken of the severed nose,

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Read before the Elizabeth, N. J., Medical Society, March 20, 1934.

which was left in the wreck. The child was rushed to the hospital. As soon as the surgeon saw the patient he sent a messenger post-haste to look for the nose. It was found, and an attempt was made to graft it on; but too much time had elapsed, and the operation was not a success. I saw the patient for the first time two months after the accident and made use of a flap from the forearm in reconstructing the organ. A flap from the forehead would have been preferable, but this was not allowed by the parents, because of possible additional scarring.

Unless the person who first sees the victim of an automobile accident is familiar with the management of the particular injury received, the results of primary emergency surgical intervention should be subjected to review by one who is experienced in this field.

To illustrate this point: Two women were driving a small car on a country road when they met another car coming from the opposite direction. Their car was forced off the road and upset, and a piece of glass from the broken wind-shield made a clean amputation of the driver's nose at a point just below the ends of the nasal bones. The amputated portion remained attached to the upper lip by two narrow strips of skin. With rare presence of mind, her companion replaced the nose and held it in position by means of a bandage until the patient was seen an hour later by a surgeon. The physician evidently was unfamiliar with rhinoplastic methods, for he sutured only the skin and subcutaneous tissues. The external cosmetic effect was fair, but the respiratory function of the nose was destroyed, for the mucous membrane and the lateral cartilages had curled up in the nose, obstructing the air passages completely. There remained also perforation of the septum. In this case, if a competent rhinoplastic surgeon had been consulted shortly after the primary, emergency work had been done, it is fair to assume that a better result might have been secured. I saw the patient two months after the accident; at this time the large amount of scar tissue precluded the possibility of a perfect result. I did, however, succeed in establishing a fair breathing space by means of an extensive intranasal plastic operation involving the use of mucous membrane flaps and skin grafts.

The wonderful vitality of the nasal tissues (due to their abundant blood supply) and the comparative immunity which they possess to the pathogenic bacteria normally resident in the nose enable the rhinoplastic surgeon to perform feats in the way of salvaging injured structures that the surgeon in other fields would not even attempt.

In cleaning up badly lacerated and contused wounds of the nose and face preparatory to adjustment of displaced parts and suturing of external wounds, one should keep clearly in mind that the object of one's efforts is not only to restore the function, but also to secure cosmetic results as nearly perfect as possible. The natural surgical advantages I have just mentioned do not warrant the omission of the usual

aseptic and antiseptic precautions; in fact, these should be rigidly carried out, especially if the injured parts have come in contact with the filth of the roadway. If this has happened, two possible complications should be considered, aside from infections due to pyogenic bacteria: (1) tetanus and (2) the presence in the macerated tissues of dirt and carbon from the roadway.

Fractures of the nose are always compound intranasally, and they may be so externally as well. Under these circumstances, especially if the tissues are badly soiled and there are deep pockets, there is always danger of tetanus. In my opinion, therefore, such patients should be given tetanus antitoxin as soon as possible.

I may mention here that a number of cases of tetanus have been reported, despite the fact that the patients had received preventive inoculation at the proper time. In explanation of the failure to protect, it has been suggested that reinfection occurred, for it has been found that tetanus antitoxin disappears from the blood on the seventh or eighth day after it has been administered. It is believed by some, therefore, that a second dose should be given on the eighth day, if the wound is still open or if it is believed that any circumstance in the case especially favors the development of tetanus.

The dust of nearly all roads contains carbon from the exhaust-pipes of the countless automobiles that pass over them. When this is ground into the macerated tissues of the nose and face, its removal is difficult. If it is not thoroughly removed, however, the tattoo marks, which are deep purple and very unsightly, will remain indefinitely.

When the framework of the nose has been fractured and the segments displaced, I know of no better method by which they may be brought into proper position and held securely until fixation has occurred than the application of the bridge splint, an instrument that I devised many years ago.

Physicians have been slow to recognize the fact that it is just as important to set a broken nasal bone properly as it is to set a fracture in any other part of the body. It is also clear that this should be done promptly, for bony union in this area occurs more quickly than elsewhere in the body, and maladjustment is certain to be followed by deformity and nasal obstruction—conditions that are far easier to prevent than to cure. One should never lose sight of the fact that the framework of the nose constitutes an arch that is composed of an indefinite number of interdependent segments. If so much as one of these segments is displaced or destroyed, the relative height and breadth of the arch will be altered, and the external contour of the nose will be changed. It may be readily understood, therefore, why it is so important for the structural elements to be saved and properly adjusted as soon as possible after the injury. The need for this precaution is emphasized

if the patient is young, for the deformed noses and deflected septums of adult life are usually due to neglected or improperly treated injuries to the nose during childhood.

Unless the patient is seen immediately after the accident, the swelling of the tissues may be so great that it is impossible to determine accurately the extent and character of the injury. Under these circumstances, if there is a fracture, it is usually impossible to adjust the broken, displaced segments, and one must wait until the swelling subsides. I have found my nasal water-jacket for the continuous application of either heat or cold useful in the management of these cases; it is effective in reducing the swelling.

The value of roentgenograms in determining the extent of the injury and the position of the displaced segments of the nasal arch, especially if the patient is an adult, cannot be overestimated. It is essential, however, for the roentgenographer to have a practical knowledge of the anatomy of the nose and to have special technical skill for work in this area, not only in taking the roentgenograms but also in interpreting them.

In my opinion, the surgeon should have a personal consultation with the roentgenographer before he attempts to treat the patient, especially if the apparent position of the segments will make the adjustment difficult.

After the operation, additional roentgenograms should be taken in exactly the same position as the first. When comparison is made between these two sets of roentgenograms, a fairly accurate evaluation of the results of the operation may be made.

In cases in which the fractured bone is not badly comminuted and in which there is no apparent danger of the nasal arch collapsing after it has been adjusted, the use of the bridge splint is unnecessary. In such cases I frequently rely on a well padded copper splint placed over the entire nose and cellophane-covered gauze packing in each nasal cavity.

Immobilization after adjustment is important. This should be maintained for at least ten days. Fixation usually occurs quickly, and one may expect bony union in this area twenty days after a fracture.

It is not my purpose to discuss here the management of old fractures and dislocations that have resulted in deformity and obstruction to nasal breathing. I may say, however, that it is necessary to refracture and completely mobilize the nasal framework before attempting to adjust the parts. It may be necessary also to remove some of the scar tissue (intranasally of course) and to resect the thick, irregular septum. The cartilage from the latter may sometimes be used in rebuilding the nasal bridge. More frequently, however, it is better to use, as I originally suggested, a transplant composed of conjoined bone and cartilage, which has been removed at the time of operation from the patient's rib. This

use of autogenous transplants of bone and cartilage fulfils the conditions necessary to maintain the physiologic relations between the tissues of the body.

Bone and cartilage, when properly introduced for the purpose of correcting a depressed nasal deformity, remain indefinitely, as has been shown in the numerous roentgenograms in some of my oldest cases.

Foreign bodies, such as ivory, vulcanite and celluloid, are used by some surgeons as implants. It should be remembered, however, that these substances are never nourished by the blood; they never become a part of the living body and are therefore subject to the vicissitudes that surround foreign matter in any other part of the body: They may be expelled, owing to necrosis caused by pressure, to external traumatism or to infection from the blood stream during an attack of influenza or some other acute infectious disease. This disaster may not occur until some time after the operation, but it is a menace that the patient must constantly face; he should be apprised of this fact before the operation.

In conclusion, injuries to the nose and face so frequently involve serious consideration of both functional and cosmetic problems that they merit the most skilful attention, and it is the duty of the clinician to deal *physiologically* with the defects which he seeks to correct in order that he may be reasonably sure of the permanency of his results.

140 East Fifty-Fourth Street.

PRINCIPLES UNDERLYING CILIARY ACTIVITY IN THE RESPIRATORY TRACT

II. A COMPARISON OF NASAL CLEARANCE IN MAN, MONKEY AND OTHER MAMMALS

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AND
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The cilia within the nose and paranasal sinuses are the chief agent in maintaining the normal clearance of the nose. Their integration, reducing to a minimum uneven stresses on the mucous sheet, is maintained in spite of the structural complexity of the mammalian nose. Such a delicate balance of directional movements and forces must operate in conformity with certain principles which, once revealed, will serve as a standard of measurement by which the rationale of some clinical procedures may be evaluated.

That such principles exist became evident as a result of studies [1] on the ciliary movement in the nasal cavity and maxillary sinus of Macacus rhesus. Yates [2] previously published an account of mucous drainage in the posterior part of the human nose. These observations have been admirably supplemented by those of Hilding,[3] who extended this survey on man to include the inferior two thirds of the nasal fossa. Unfortunately, the pattern of ciliary movement in the superior third, which has particular interest and significance in all the other mammals examined, has not as yet been plotted for the human nose. The obser-

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1. Lucas, A. M.: (*a*) Direction of Ciliary Movement in the Nasal Cavity of Macacus Rhesus (Demonstration): A Preliminary Report, Tr. Am. Laryng., Rhin. & Otol. Soc., 1931, p. 172. (*b*) The Nasal Cavity and Direction of Fluid by Ciliary Movement in Macacus rhesus (Desm.), Am. J. Anat. **50**:141 (March 15) 1932.

2. Yates, A. L.: Methods of Estimating the Activity of the Ciliated Epithelium Within the Sinuses, J. Laryn. & Otol. **39**:554 (Oct.) 1924.

3. Hilding, A.: (*a*) Ciliary Activity and Course of Secretion of the Nose, Proc. Staff Meet., Mayo Clin. **6**:285 (May 13) 1931. (*b*) The Physiology of Drainage of Nasal Mucus: I. The Flow of the Mucus Currents Through the Drainage System of the Mucosa and Its Relation to Ciliary Activity, Arch. Otolaryng. **15**:92 (Jan.) 1932.

vations herein reported on the noses of laboratory and domestic mammals [4] show that the pattern of mucous clearance, the gradient axis of increasing ciliary activity and the direction of inhaled air currents in these animals differ from those found in man and the monkey. Many experiments have been made in an attempt to explain why this is so.

MATERIAL AND METHODS

The previous study was based on twenty-nine Macacus rhesus monkeys; for this investigation of the ciliary pattern six mice, twenty-one rats, nine cats, twenty rabbits, twenty-five cow heads and twenty-one sheep heads [5] were required. On no one animal could more than a small portion of the ciliary currents be mapped, because after a short but varying period of time the mucus ceased to move and the cilia lost their motility.

The usual difficulty in obtaining records from the medial surface of the inferior concha of the rabbit was overcome, and an adequate flow of mucus was produced by injecting pilocarpine intravenously a few minutes before the animal was killed.

Most of the smaller animals, such as the mouse and rat, were killed by decapitation; some of the cats were etherized, but most of the cats and rabbits were first rendered unconscious by a blow on the head and were then immediately decapitated. The heads of cows and sheep, furnished by the packing house, came from animals killed about from one half to three quarters of an hour previously.

The heads of the smaller animals were placed in a moist chamber and examined with the Greenough binocular microscope. The heads of the others, such as the cat, rabbit and sheep, were studied on the stage of the microscope, without precautions to prevent drying. The nose of the cow, because of its large size, was not studied *in toto*. Excised pieces of the mucous membrane were examined separately, and from these the pattern of the whole was constructed.

The direction of ciliary movement was determined in two ways: first, by observing the passage of the mucous sheet, which was made apparent by the presence of bubbles on the surface or by the addition of dry particles of carbon, and second, by employing the reflection method described in the first article of this series,[6] which makes visible the movements of the cilia. Though there are errors in each method, these, fortunately, are of such a nature that they are eliminated by combination of the two.

OBSERVATIONS

The domestic mammals and the rodents possess a lateral nasal wall constructed on a common plan, and although the parts are modified in adaptation to differences in the shape of the nose and the habits of

4. Observations on eighteen young opossums were included in a preliminary report (Lucas, A. M., and Douglas, L. C.: Direction of Flow of Nasal Mucus, Proc. Soc. Exper. Biol. & Med. **31**:320 [Dec.] 1933), but the final conclusions concerning the ciliary pattern during development await additional material.

5. The officers of the Independent Packing Company gave us all the cow and sheep heads needed, as well as available space and facilities in their plant for a period of two weeks while obtaining the records on these animals.

6. Lucas, A. M.: Principles Underlying Ciliary Activity in the Respiratory Tract: I. A Method for Direct Observation of Cilia in Situ and Its Application, Arch. Otolaryng. **18**:516 (Oct.) 1933.

the animal, they may readily be homologized. The same may be said for the animals within the primate group, but between the primates and the other mammals there are such structural differences that homologies are uncertain. The terminology of the parts of the nose of the animals discussed indicates location rather than phylogenetic relationship.

The three conchae—the ethmoid, superior and inferior—in the nose of mammals (other than primates) are shown in their simpler form in the rat (fig. 1 *A*). The form of the superior concha is relatively constant, but the inferior concha may present the intricacy of structure found in the rabbit (fig. 1 *C*) or regress before extensive development of the ethmoid concha, as in the cat (fig. 2 *A*). Variations of the ethmoid concha are shown mostly in the degree of anterior development.

This study deals only with the superior, middle and inferior meatuses. The form of the superior meatus is fairly constant in different mammals. That of the inferior meatus, however, is particularly variable (compare the inferior meatus of the rat [fig. 1 *A*] and that of the cow [fig. 2 *C*]). The middle meatus is always large, but frequently is not visible until after removal of one of the conchae. Its anterior continuation, the location of which is indicated in figures 1 *B*, 1 *D* and 2 *C*, has proved to be an important region in relation to the pattern of mucous flow. It occupies the space formed by the cartilages of the anterior end of the nose and is separated from the naris by the infolded margin of the ala. The fossa is confluent with the naris by a slit of variable size. No name was found for this region in textbooks on veterinary or comparative anatomy.[7] The designation fossa of the middle meatus is suggested and will be used.

Pattern of Ciliary Currents.—Rat: The mucous layer, which passes across the medial surface of the superior concha, originates at the olfactory border and the lip of the sinus ostium (fig. 1 *A*). Its pathways conform to the marginal contours of the concha, and it accumulates at the stratified epithelium near the anterior end of the nose.

Less extensive drainage toward the anterior end is accomplished on the medial surface of the inferior concha because much of the mucus is diverted downward to unite with the streams along the floor, whence it passes posteriorly.

The ciliary streams on the several folds of the ethmoid concha and the depressions between them follow, in general, the contours of these structures and later curve to merge with the currents passing through the choana. None of this material reaches the anterior end. The beat of the cilia adjacent to the olfactory epithelium is such that the mucous layer is pulled forward across this nonmotile area.

7. The absence of a properly descriptive term in the literature was confirmed by Prof. J. P. Schaeffer in a personal communication to the authors.

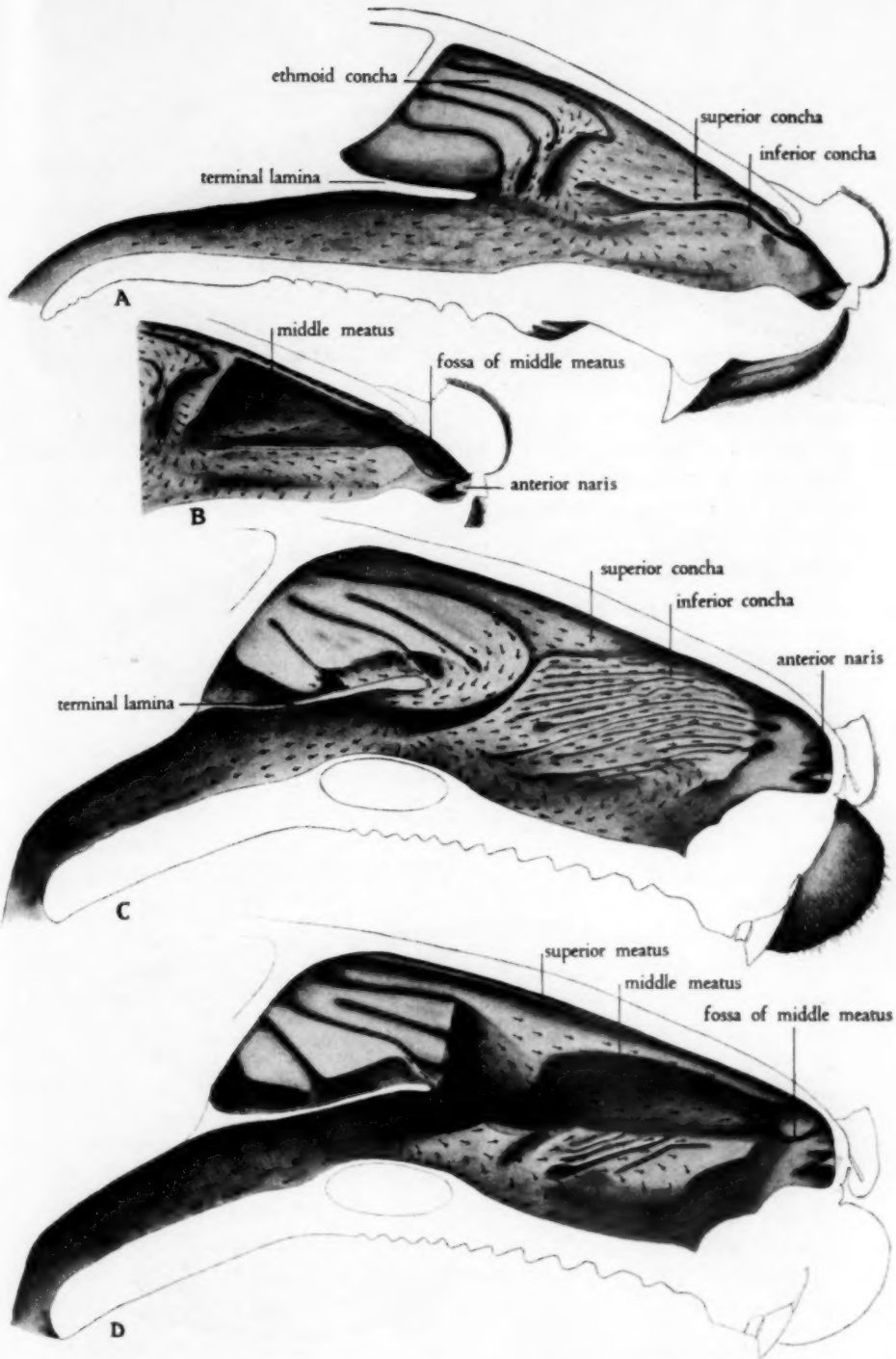

Fig. 1.—*A*, lateral wall of the nasal fossa of the rat; magnification, 3 ×; *B*, middle meatus and fossa of the middle meatus of the nasal cavity of the rat, exposed after removal of the superior and inferior conchae; magnification, 3 ×; *C*, lateral wall of the nasal fossa of the rabbit; magnification, 1.7 ×; *D*, middle meatus and fossa of the middle meatus of the rabbit, exposed after removal of the ethmoid and inferior conchae; magnification, 1.7 ×.

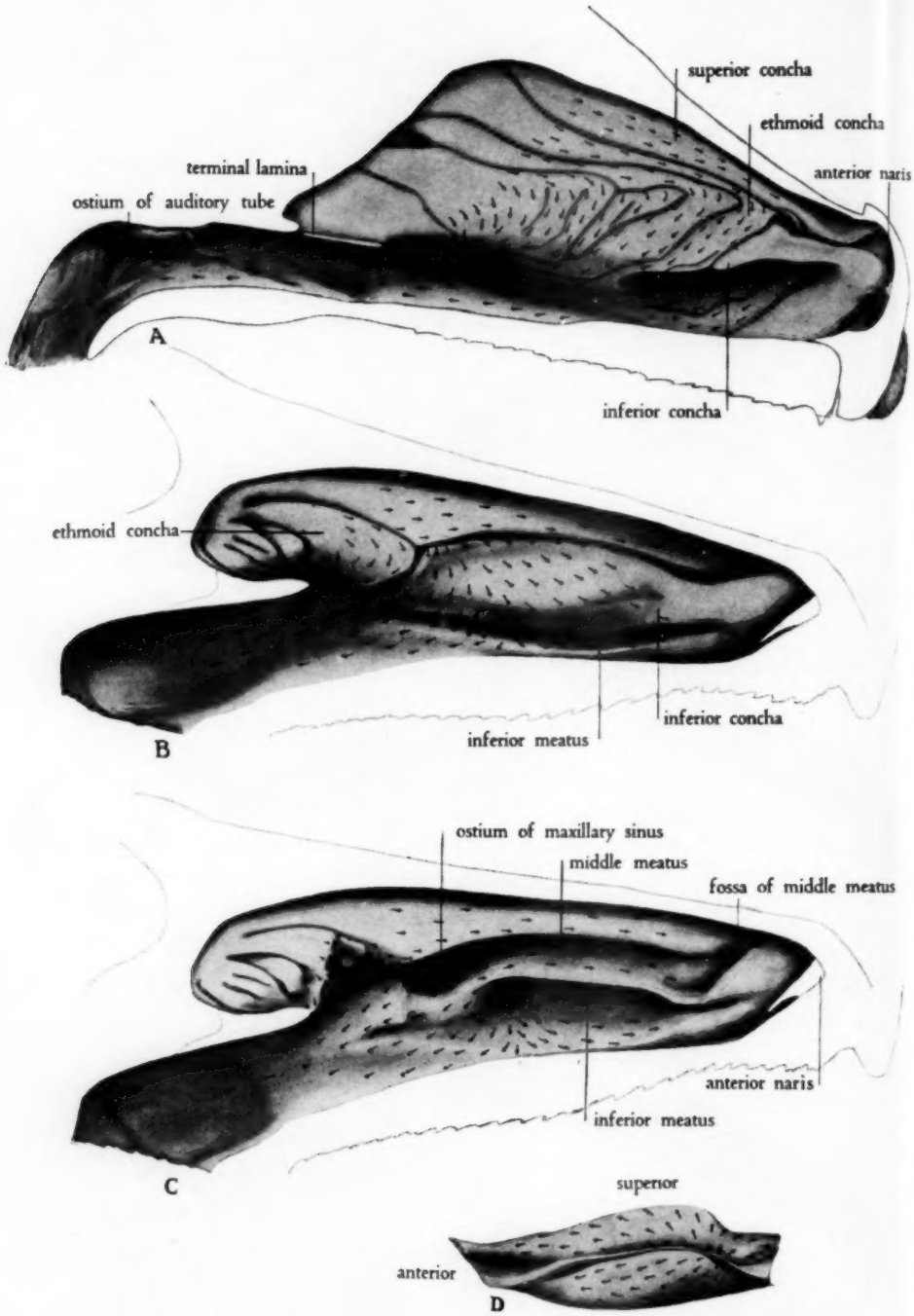

Fig. 2.—*A*, lateral wall of the nasal fossa of the cat; magnification, 2.2 ×; *B*, lateral wall of the nasal fossa of the cow; magnification, ½ ×; *C*, middle and inferior meatuses of the cow, exposed after removal of the inferior concha; magnification, ½ ×; *D*, lateral view of the inferior concha, which was removed from the nose shown in figure *C*; magnification, ½ ×.

The mucous sheet discharged from the sinus spreads out in a fanlike manner from the ostium. It is carried in part over the superior concha into the middle meatus. Some of it crosses the inferior concha, and a large part is directed backward toward the nasopharynx.

The mass of material carried into the middle meatus is greater than the arrows indicate (fig. 1 *B*). This material, as well as that present on the walls of this relatively spacious cavity, is transported by ciliary action, which here is particularly vigorous, to the fossa of the middle meatus and accumulates on the stratified epithelium of this region.

Mouse: The lateral wall of the nose of the mouse is constructed similarly to that of the rat, except that the first fold of the ethmoid concha is relatively larger; the spaces opening into the ethmoid meatuses are proportionally wider, and the gap between the opposing edges of the superior and inferior conchae is greater.

The pattern of ciliary currents is practically a duplicate of that in the rat. There is, in the upper two thirds of the nose, the same broad stream of currents flowing toward the anterior nares, and in the inferior part there is a narrow, posteriorly directed stream, which merges with the currents of the floor and continues into the nasopharynx, where it is joined by material from the ethmoid concha. As in the rat, no sharp break exists between anteriorly and posteriorly directed currents. The ostium of the maxillary sinus is located closer to the middle meatus than in the rat, and as a result a larger portion of the mucus from the sinus passes into this meatus or along the edges of the conchae; some of it, however, merges with the streams that flow posteriorly through the choana.

Rabbit: The surface of the inferior concha of the rabbit (fig. 1 *C*) is characterized by numerous parallel folds which extend from the floor diagonally forward and upward. The direction of the flow of mucus over the medial surface of this structure parallels that of these folds, except in the regions adjacent to the floor, where it follows a curved path forward and downward and, approaching the floor, turns backward.

A large part of the medial surface of the ethmoid concha is occupied by olfactory epithelium, indicated in figure 1 *C* by the absence of arrows. The cilia bordering this area draw the mucous sheet forward. After the layer is pulled beyond the end of the terminal lamina [8] it is curved in paths corresponding to the contours of the anterior end of the ethmoid concha and arrives beneath the terminal lamina, whence it passes to the lateral nasopharyngeal wall.

8. For the cartilaginous extension anterior to the presphenoid bone the term terminal lamina was employed by Mihalkovics (Anatomie und Entwicklungsgeschichte der Nase und ihrer Nebenhöhlen), in von Heymann, P.: Handbuch der Laryngologie und Rhinologie, Vienna, A. Hölder, 1900, vol. 3, p. 1.

Removal of the ethmoid and inferior conchae exposes the extensive inferior face of the superior concha, as well as the middle meatus (fig. 1 *D*). The ciliary streams on the medial and inferior faces of the superior concha follow approximately parallel paths anteriorly. A large part of the mucous sheet arising behind the ethmoid concha passes forward, enters the middle meatus, spreads over the walls of this cavity and finally arrives at the stratified epithelium lining the fossa of the middle meatus.

The contents from the sinus, discharged from the ostium behind the ethmoid concha, are conveyed by cilia to the middle meatus, the inferior concha, the floor and the nasopharynx.

Cat: The lateral wall of the cat's nose differs considerably in structure from that of the rodent's; differences in the ciliary pattern also exist. The pattern in the cat's nose more nearly resembles that in man and the monkey than do the patterns observed in the noses of the other mammals studied.

All the streams on the medial surface of the superior and ethmoid conchae originate from the olfactory border by paths which begin at right angles to the margin of this nonciliated area (fig. 2 *A*). The anterior direction of movement on the superior concha continues to a termination at the stratified epithelium. Streams on the ethmoid concha usually follow its curves and folds, and along its inferior face they curve backward before leaving it to pass to the lateral wall. In some cases the streams, instead of following the contour of the concha, move diagonally forward and downward, and apparently the mucous sheet is carried across the depressions between the folds.

The mucous sheet covering the inferior concha is propelled backward to the lateral wall and floor of the nose and continues thence directly posteriorly to the nasopharynx. Anteriorly directed streams are apparently lacking on this concha in the cat.

In figure 2 *A* the ostium of the auditory tube is indicated. It is protected more by its location in relation to the adjoining folds than by ciliary action. There is, however, some tendency for the ciliary currents to divide and pass around this opening, but it is not modified to the same extent as depicted in man by Hilding[3b] and Yates[2] (fig. 3 *A*).

Removal of the ethmoid and inferior conchae exposes a triangular-shaped middle meatus similar to that found in the rat, and the pattern across the surface is likewise similar in that the ciliary action in this protected crevice is vigorous and its direction of movement is toward the fossa of the middle meatus.

Most of the material extruded from the maxillary sinus reaches the middle meatus, but the part carried toward the nasopharynx passes

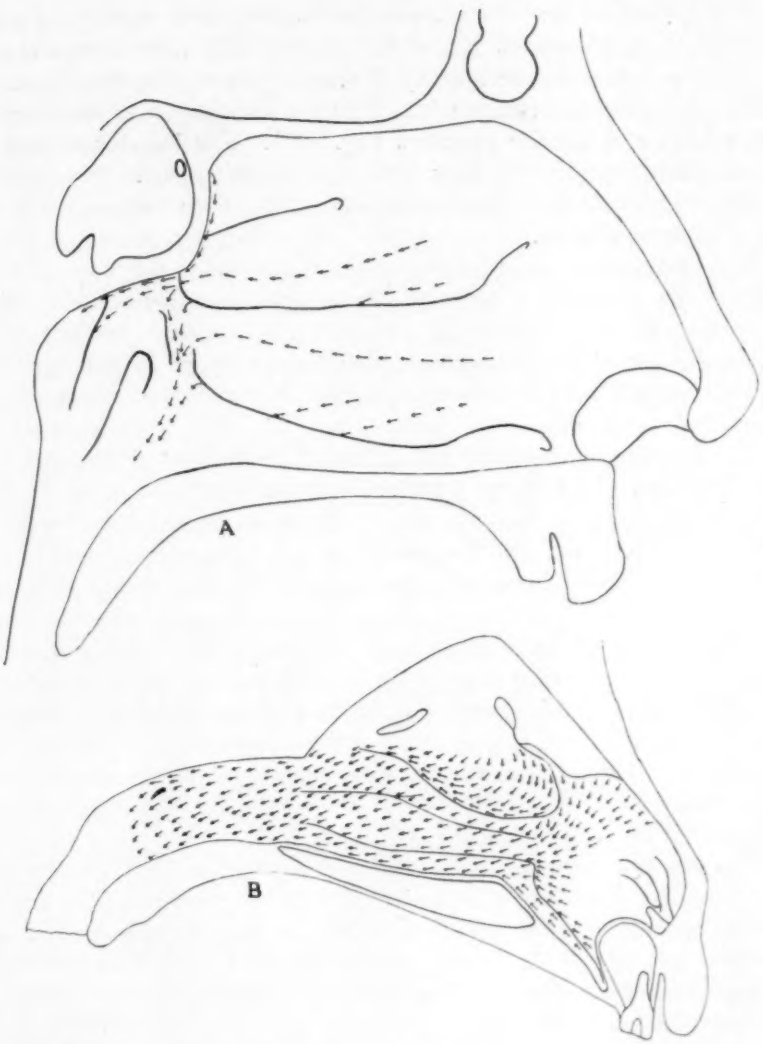

Fig. 3.—*A*, diagram of the lateral wall of the human nasal fossa, showing by means of arrows the direction of ciliary currents and mucous drainage, as presented by Yates [2] and Hilding.[3b] *B*, diagram of the lateral wall of nasal fossa of Macacus rhesus, showing by means of arrows the direction of ciliary currents, as presented by Lucas.[1b]

through a channel formed by a shallow arch on the lateral face of the ethmoid concha.

Cow: The ruminants studied—the cow and the sheep—possess an inferior concha the medial face of which (fig. 2 *B*) resembles in shape the same structure in the monkey and, to a less degree, that in man. Its infolded scroll-like laminae (fig. 2 *D*) are associated with well developed middle and inferior meatuses (fig. 2 *C*). The inferior meatus is set off from the adjacent floor by a well defined ridge. The middle meatus bears the crescent-shaped ostium of the large confluent sinuses found in these animals.

The ciliary pattern on the superior and ethmoid conchae (fig. 2 *B*) protects the olfactory area in the same way already noted in other mammals. On the former the streams continue along parallel paths toward the anterior end; on the latter they conform to the contours of the first fold and become concentrated at the end of the terminal lamina before passing to the lateral wall.

The inferior concha attains clearance of its surface in almost opposite directions. The ciliary currents in the anterior two thirds course forward and downward toward the anterior nares; in the posterior third the direction is principally downward, with a tendency to curve backward as the inferior margin is approached. The line which separates the division of streams in two directions is a diagonal one extending anteriorly from the superoposterior angle toward the inferior margin. Figure 2 *D* is a posterior view of the concha; on both the superior and the inferior fold of this structure a similar diagonal division of currents is to be noted. There is a tendency toward rotation of the streams in that the superior fold contributes its mucous layer to the medial face and the mucous sheet on the medial face curves over its inferior edge to arrive on the lateral side of the inferior fold.

The inferior surface of the superior concha, exposed by removal of the inferior concha, is only partially shown in figure 2 *C*. The ciliary streams on the posterior end of this face are directed forward as far as the ridge, where they turn upward on the medial surface. The streams beyond the ridge continue along parallel paths toward the fossa of the middle meatus.

The divergence of mucous flow in the middle meatus begins at the lower lip of the sinus ostium. The currents ultimately reach the fossa of the middle meatus or pass behind the ethmoid concha to arrive in the nasopharynx.

The same general plan of organization into anteriorly and posteriorly directed streams occurs in the inferior meatus. Records of direction of beat along the floor of the nose were not obtained in the anterior region, and in only a few animals were ciliary movements observed as far forward and downward as indicated by the arrows.

The extent of ciliary activity in the nasopharynx is variable and, in general, could be noted farther posteriorly in calves than in cows. The greatest spread ever found is noted in figure 2 *C*; usually, activity terminated in the region of the choana. The disappearance of cilia may be associated with regurgitation, since it was noted that wherever regurgitated material rested on the nasal wall it stopped all underlying ciliary movement.

Sheep: Structurally, the nasal cavity of the sheep is almost a duplicate of that in the cow, and the pattern of ciliary streams, including the separation of streams along a diagonal line into anteriorly and posteriorly directed currents, is the same. In addition, it has been possible to plot the mucous flow along the floor, which begins at the stratified epithelium and progresses backward to the nasopharynx. These currents are joined by streams continuing from the inferior meatus, which extend across the elevation shown in figure 2 *C* and turn posteriorly with the streams along the floor.

Rate of Mucous Flow.—A cursory comparison of the ciliary pattern of movement in the laboratory and domestic mammals already described with the pattern in primates (fig. 3 *A* and *B*) readily reveals marked differences in plan and organization. The endeavor to learn the underlying principles which determine the pattern requires that all other physiologic attributes of the nose be considered in an effort to seek correlations which may suggest the nature of these principles by their modes of action. Therefore, the rate of mucous flow in different parts of the nose and, later, the direction of inhaled air currents will be considered.

In the monkey's nose there is a vigorous propulsion over the floor and the inferior concha and a continued decrease in the rate of flow from the floor toward the roof (Lucas [1b]). Man also exhibits vigorous ciliary movements in the lower part of the nose. No records of ciliary activities in the upper part of the human nose have as yet been published.

It was observed, on the other hand, in all the laboratory and domestic mammals examined that the regions of greatest velocity are the surfaces of the superior concha, adjacent parts of the ethmoid concha and the middle meatus. The medial surface of the inferior concha in all the mammals from the rat to the cow showed poor ciliary activity. It was particularly difficult to secure records in that region in the rabbit, and it was necessary to inject pilocarpine, which increased the mucous flow and made records possible. The floor likewise showed especially weak ciliary movements, and the cow affords a striking example of this feature, since no records were obtainable in this region from any of the twenty-five heads examined.

Poor ciliary movement cannot be attributed to death of the animal, because cessation of mucous propulsion does not occur at that time. A monkey's head which had been cleaved lengthwise to expose the nose was left on the laboratory table wrapped in a towel saturated in Ringer's solution for about eighteen hours, after which some cilia were observed to be still vigorously active.

Variations in speed of mucous flow may be due to several factors, of which any one alone might be effective. Those which involve the cilia are: the number of vibrations per unit of time, the amplitude of the vibration, the length of the cilia, the ratio of ciliated to nonciliated area and the susceptibility of the ciliated epithelium to intrinsic and extrinsic agents which modify the rate and degree of movement. Factors which involve the mucus are the thickness of the layer, its original viscosity at the time it is secreted and its viscosity after changes due to the passage of air and the addition of serous fluids.

TABLE 1.—*Ciliary Length in Different Regions of the Monkey's Nose*

Region	Number of Cells, Measured	Average Length of Cilia, Microns
1. Superior half of septum	23	7.6
2. Inferior half of septum	29	7.6
3. Medial face of middle concha	33	7.9
4. Lateral face of middle concha	6	7.5
5. Ventral face of middle concha	5	7.8
6. Superior half of middle meatus	14	6.8
7. Inferior half of middle meatus	21	7.2
8. Inferior concha	35	7.1
9. Inferior meatus and floor	35	6.8
10. Nasopharynx	31	7.2
11. Ethmoid infundibulum and maxillary sinus	59	6.7

Length of Cilia.—Merton[9] reported that the more rapid mucous flow in certain regions of the frog's mouth is due to the occurrence in them of particularly long cilia. A survey of ciliary length in different parts of the monkey's nose was accordingly undertaken. Heads of recently killed monkeys were used; scrapings of small areas of the epithelium were placed on a slide, and the length of the quiescent cilia was measured (table 1).

The average length for the different regions varied from 6.7 to 7.9 microns, a difference of 1.2 microns or an increase of 18 per cent of the smaller value. The cilia were slightly longer than has been reported in the literature.[10] The rates of mucous flow per second previously recorded[1b] are as follows: floor, 110.7 microns; inferior concha, 52.7 microns, and medial surface of the middle concha, 32.5 microns; along

9. Merton, H.: Studien über Flimmerbewegung, Arch. f. d. ges. Physiol. **198**:1, 1923.

10. Lucas, A. M.: Ciliated Epithelium, in Cowdry, E. V.: Special Cytology, ed. 2, New York, Paul B. Hoeber, Inc., 1932, sect. 11, p. 408.

the roof the flow was even slower. As shown in table 1, the long cilia occurred in the region of slow movement, and almost the shortest were observed on the floor, where the flow is most rapid.

It is, therefore, doubtful whether this difference in ciliary length is significant; moreover, technical errors involved in measurement account for a certain part of the difference between the highest and lowest values.

But if it is assumed that the difference in length is significant, the effect of this difference on the propulsion of the mucous layer must depend on the velocity of movement of the tip of the cilium, for it only is in contact with the mucous layer. The velocity would have to be directly proportional to the ciliary length, if the other variables in the calculation remain constant. Consequently, the greatest variation in rate estimated from ciliary length would be 18 per cent, whereas the actual difference observed was about 260 per cent. Thus, it is again evident that variations in ciliary length do not account for variations in the rate at which the mucous layer moves over the surface.

Ratio of Ciliated to Nonciliated Areas.—Different proportions of ciliated to nonciliated areas is suggested as a possible explanation for the differences in the rate of the mucous flow. It was noted, for example, both by Hilding [3b] in man and by Lucas [1b] in the monkey, that the anterior tip of the middle concha (region *b*, fig. 4) is sluggish in its clearance of overlying mucus, and it was also observed that, associated with this sluggish activity, patches of nonciliated epithelium which tended toward a stratified type occurred in this region.

Not only do the stratified cells serve to lessen the proportionate area occupied by ciliated cells, but it is conceivable that an excessive preponderance of goblet cells would also act in the same way to lessen the effective motility of the epithelial surface. Some preliminary measurements were made, therefore, to determine the ratio of the exposed free surface of ciliated and nonciliated cells. Small pieces of epithelium, as shown in figure 4, were carefully removed from the underlying bone. Twenty-five such samples were taken, but records were obtained from only four (table 2). The reason for this was the difficulty in obtaining a section cut exactly parallel with the surface over an area sufficiently large for adequate measurements. An example of a satisfactorily cut section is shown in the photograph (fig. 5) of region 4. The section must include the basal granules of the ciliated cells and the openings of the goblet cells. Anything at a level below this gives an inaccurate ratio between the motile and secretory elements of the epithelium, owing to the bulging of the goblet cells, as may be noted along the left edge of figure 5, where the section cuts below the surface. That this method is more accurate than cross-sectioning for evaluating the ratio of two

types of cells has been demonstrated by Benoit [11] in his study of a similar problem in the epididymis.

Epithelia in regions 3 and 4 (fig. 4 and table 2) are from the median surface of the middle concha, in region 9 from the inferior surface of this structure and in region 23 from the superior face of the inferior concha. The percentage of ciliated surfaces for the middle and inferior conchae compared with the rates of mucous flow in these regions makes it appear improbable that such minor differences in ratio could account for the greater differences in the rate of mucous passage. On the other

TABLE 2.—*Proportion of Ciliated to Secretory Surface in the Nose of Macacus rhesus*

Region	Goblet Cell Count	Average Free Surface of a Goblet Cell, Square Microns	Range, Square Microns	Total Free Cell Surface of Goblet Cells in 10,000 Square Microns	Openings of Glands	Area of Openings of Glands, Square Microns	Total Nonciliated Area in 10,000 Square Microns	Ciliated Area in 10,000 Square Microns	Percentage of Ciliated Surface
3	46	41.0	1.8- 91.8	1,640.2	..	....	1,640.2	8,359.8	83.6
4*	40	52.1	2.3-152.0	2,084.0	3	119.7	2,203.7	7,796.3	78.0
9†	31	50.9	2.5-125.0	1,577.9	..	....	1,577.9	8,422.1	84.2
23	54	47.6	6.6- 98.7	2,540.4	1	49.2	2,619.6	7,380.4	73.8

* The values given are the average of four counts made in this region.
† The epithelium of this area was taken from the inferior face of the middle concha.

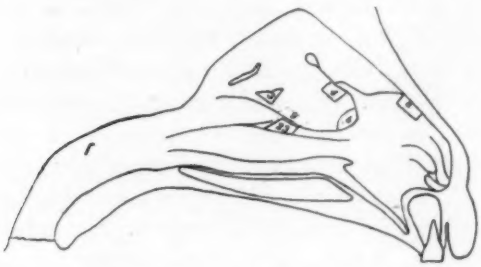

Fig. 4.—Diagram of the nose of Macacus rhesus. Regions 3 and 4 are located on the medial surface of the middle conchae, region 9 on the inferior surface of this concha and region 23 on the superior surface of the inferior concha. The text and table 2 give data on the epithelium in these regions and also in regions *a* and *b*.

hand, when the proportion of goblet cells is particularly great, as is the case in region *a*,[12] perceptible mucous passage is almost lacking. There-

11. Benoit, M. J.: Recherches anatomiques, cytologiques et histophysiologiques sur les voies excrétoires du testicule, chez les mammifères, Arch. d'anat., d'histol. et d'embryol. **5**:173 (Feb.) 1926.

12. Although actual measurements are lacking, it was noted that when smears of fresh tissue were made from region *a*, ciliated cells were few and goblet cells were abundant. This was also confirmed in microscopic cross-sections.

fore, the proper balance of ciliated and secretory elements to produce the maximum motile efficiency remains to be worked out. It is obvious that too great a preponderance of the mucous type of cell, such as occurs near the roof, is detrimental to rapid clearance, and when stratification occurs no movement or lubrication is to be expected, except by the mechanism of traction described by Hilding.[3] It also indicates that relatively large differences in the rate of mucous flow can occur in regions where the differences in percentages of ciliated areas are relatively small and probably not significant. Thus, it must be concluded

Fig. 5.—Surface of epithelium from region 4 (fig. 4), showing relative areas occupied by ciliated and secretory elements.

that some other factor determines the rate of nasal clearance. In a search for this factor the nature of the mucous layer was examined.

Double Nature of the So-Called Mucous Layer.—When the rate of mucous flow for the monkey's nose was recorded the fact had not yet been established that while the cilia were vigorously active the overlying mucous layer could remain quiescent. This was discovered only after a method for observing the cilia by reflected light had been developed.[5] It was then immediately evident that the mucous layer was really made up of two parts: an overlying viscid sheet and a layer of serous fluid which furnished the medium in which the cilia vibrate.

These relationships are diagramed in figure 6, which is constructed on Gray's [13] figure 8 showing that the active phase occupies about one fifth of a complete ciliary vibration and the recovery phase takes about four fifths of this period. If these relationships in regard to time hold for the mammalian nose, at any instant only one fifth of the total number of cilia are involved in the propulsion of the mucous layer. But it can readily be seen from the diagram that the tips of these, which are in the forward phase of their movement, present to the under surface of the mucous layer a much greater area of activity than is occupied by the tips of the cilia in the recovery phase.

The evidence that two layers instead of one lie above the cellular surface is as follows:

1. The fact already mentioned that the cilia may be fully active while the mucus fails to move indicates that the cilia must be surrounded by a fluid of different viscosity than mucus.

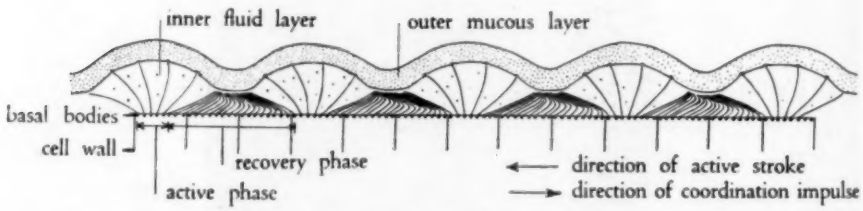

Fig. 6.—Diagram in which the cilia are arranged to show correlation of the relationships of their movements; the locations of the two parts of the so-called mucous layer—the mucus and the fluid components—are shown in their relation to the vibrating cilia.

2. Removal of a normal unevaporated mucous layer and its replacement with Ringer's solution greatly reduces the speed with which particles added to the surface are transported, although the cilia are as vigorously active as they were before. Hilding [14] also demonstrated under conditions in vivo in the dog's frontal sinus that "Thick, heavy mucus was handled best and most rapidly . . . and aqueous solutions required the greatest length of time." His conclusion that this is due to a difference in thickness of the transported layer does not conflict with the present consideration that two layers normally exist. It supports the suggestion that the cilia do not produce streaming cur-

13. Gray, J.: The Mechanism of Ciliary Movement: VI. Photographic and Stroboscopic Analysis of Ciliary Movement, Proc. Roy. Soc., London, s. B **107:** 313 (Dec.) 1930.

14. Hilding, A.: The Physiology of Drainage of Nasal Mucus: III. Experimental Work on the Accessory Sinuses, Am. J. Physiol. **100:**664 (May) 1932.

rents in the mucus, but that they propel it in the manner diagramed, which, because there are no retarding back eddies, results in a higher velocity than would occur if the mucus were present both around and above the cilia.

3. In one instance a foreign particle which was present in the fluid layer that surrounds the cilia was rapidly propelled along beneath the overlying mucous layer, which at the time was completely at rest, thus demonstrating again that the two layers can move independently of each other.

4. Numerous fixed and stained microscopic sections showed that only the tips of the cilia touch the mucus. The outer layer stains with mucicarmine and other stains for mucins, but the underlying fluid layer is uncolored by commonly used dyes.

The possible importance of the fluid layer as a mechanism of dissemination of bacteria and viruses makes it highly desirable that experiments be performed to demonstrate the origin of this fluid and the factors which influence its viscosity and quantity. Likewise, it becomes more important than ever to know what factors control the viscosity of the overlying mucous layer. Although the source of fluid for the fluid layer is unknown, a possible origin is the intercellular fluid which oozes to the surface of the epithelium. Because of its high vascularity, the nose is adapted to supply an abundant amount of such fluid. It is also possible that serous cells can contribute fluid, although they are usually located at the base of mixed glands and their secretions are somewhat mixed with the mucus before the combined fluids reach the surface. It has been noted by Buhrmester [15] that water and mucus are not readily miscible and that they have a different specific gravity. This may occasion separation into two layers at the surface of the epithelium, the serous secretion forming the lower and the mucous the upper.

Even the limited information concerning the interplay of the two layers permits some consideration as to how the rate of mucous flow may be influenced by their interaction: 1. Slight drying which does not affect the underlying cilia could increase the viscosity of the mucous layer so that ciliary action would fail to move it. 2. Overabundance of fluid in the lower layer could elevate the mucous sheet so that the cilia would fail to make contact with it and thus be unable to propel it along. 3. Diminution of the fluid layer to the extent that the mucus settled close to the cellular surface would slow and probably stop the action of the cilia.

15. Buhrmester, C. C.: Personal communication to the authors.

Direction of Air Currents in the Nose.—Numerous investigators [16] undertook the study of air currents through the human nose. Various procedures were employed; some were adapted to the nose of the living person, others to the head of the cadaver, to the head cut near the median plane, with the septum replaced by glass, and to plaster models of the nose. Particles such as magnesium powder, zinc stearate, carbon and lycopodium, fumes such as smoke of various kinds, volatile acids, ammonia, osmic acid and iodine were used as indicators of air currents. These methods in the hands of different investigators gave results in close agreement. Even water drawn through the nose circulates in the same path as does the air.[16c]

Attempts were made to extend our knowledge of the direction of air currents through the mammalian nose to animals other than man, in order to determine whether any correlation exists between air currents and ciliary currents. Three methods were tried:

1. The animal was placed in a box through which carbon-laden air circulated. After the animal had breathed this air for from five to ten minutes it was removed and killed with chloroform, and the lateral wall of the nose was exposed as rapidly as possible to prevent any great

16. (*a*) Paulsen, E.: Experimentelle Untersuchungen über die Strömung der Luft in der Nasenhöhle, Sitzungsb. d. kaiserl. Akad. d. Wissenschaft., math.-naturw. Kl. **85**:352 (May) 1882 (a careful study of air currents in the cadaver). (*b*) Kayser, R. L.: Ueber den Weg der Athmungsluft durch die Nase, Ztschr. f. Ohrenh. **20**:96, 1890 (a good review of earlier literature; the author used living subjects as well as cadavers). (*c*) Franke, G.: Experimentelle Untersuchungen über Luftdruck, Luftbewegung und Luftwechsel in der Nase und ihren Nebenhöhlen, Arch. f. Laryng. u. Rhin. **1**:230, 1894 (the study of air currents is subsidiary to the investigation of changes of pressure in the nose). (*d*) Scheff, G.: Contribution to the Physiology and Anatomy of the Human Nose, J. Laryng. **9**:64, 1895 (a brief report based on living subjects). (*e*) Goodale, J. L.: An Experimental Study of the Respiratory Functions of the Nose, Boston M. & S. J. **135**:487 (Nov. 12) 1896 (a study on living subjects having either a normal or pathologic nose). (*f*) Réthi, L.: Experimentelle Untersuchungen über die Luftströmung in der normalen Nase, sowie bei pathologischen Veränderungen derselben und des Nasenrachenraumes, Sitzungsb. d. kaiserl. Acad. d. Wissenschaft., math.-naturw. Kl. **109**:17, 1900 (a good review of the early literature, and a study of air currents in the normal and abnormal nasal cavity). (*g*) Parker, C. A.: Some Observations and Remarks on the Air-Currents in Nasal Respiration, J. Laryng. **16**:345 (July) 1901 (apparently unaware of the earlier work on the living subject, the author independently obtained similar results). (*h*) Burchardt: Die Luftströmung in der Nase unter pathologischen Verhältnissen, Arch. f. Laryn. u. Rhin. **17**:123, 1905 (an excellent application of preceding studies to various nasal abnormalities of clinical significance). (*i*) Proetz, A. W.: Some Intimate Studies of Nasal Function: Their Bearing on Diagnosis and Treatment, Ann. Otol., Rhin. & Laryng. **41**:125 (March) 1932 (a confirmation of earlier fundamental and clinical observations).

changes in distribution of the carbon in the nose due to ciliary action. Chloroform tends to stop the cilia more than ether.[17]

2. The decapitated head was cut along the median line, and the septum was removed and replaced with a sheet of celluloid cut to fit this space. Air leaks were closed with plaster of paris and pyroxylin (celloidin). Suction applied to the trachea drew fumes through the nose. White smoke, bromide and heated iodine were tried, but in every case the layer of smoke or gas was too thin to be visible in the small noses employed. It was observed, however, that iodine stained the tissue, and by this means the principal pathways at least could be followed.

3. The iodine method was used on the whole head. This gave more reliable results, because any deflection produced by the septum would thus also be included.

The inhaled air currents in man enter the anterior nares, arch upward toward the roof and curve down to the choana. Iodine vapor

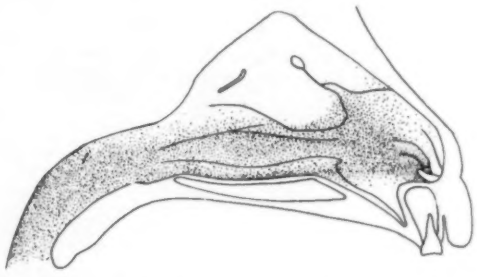

Fig. 7.—Lateral wall of the nasal fossa of the monkey, showing by the density of stippling the relative quantities of air conducted by experimental inhalation through the different parts of the nose.

drawn through the nose of the monkey (fig. 7) reveals a less sharply arched course, but shows the same tendency to curve upward. It then passes diagonally along the lower border of the middle concha and across the inferior concha. Two structures in the lateral wall serve particularly to deflect the air streams downward: first, the infolded edge of the alar cartilages, just within and above the nares, and, second, the inferior face of the middle concha. The medial margin of the latter surface extends close to the septum, thus limiting the passage of air toward the olfactory area. There is also a large quantity of air, judging by the coloration with the iodine vapor, which passes from the nares directly along the floor to the nasopharynx.

17. Lucas, A. M.: (*a*) The Nasal Cavity and Direction of Fluid by Ciliary Movement in Macacus Rhesus (Desm.), Am. J. Anat. **50**:141 (March 15) 1932. (*b*) Hill, L.: The Ciliary Movement of the Trachea Studied in Vitro, Lancet **2**:802 (Oct. 20) 1928.

Relatively little air reaches the tissue forming the roof of the nose, which is probably responsible for the predominance of goblet cells in this area. It has been demonstrated by Marchand [18] and Sternberg [19] in man and by Hilding [20] in dogs and rabbits that less than normal ventilation or complete absence of ventilation causes the epithelium to change toward a mucous cell type.

The rabbit (fig. 8) exhibits to a marked degree the functional relationship of the air currents to the laminated and grooved structure of the inferior concha. The incoming air carrying iodine stains intensely the medial surface of this structure, and the grooves deflect the air downward toward the choana. Considerable staining of the anterior tip of the ethmoid concha occurs. There is not the same tendency in the rabbit for air to arch upward as in man and the monkey. Any movement in this direction occurs immediately after the air has passed through the anterior nares. The nares are so placed that a large volume

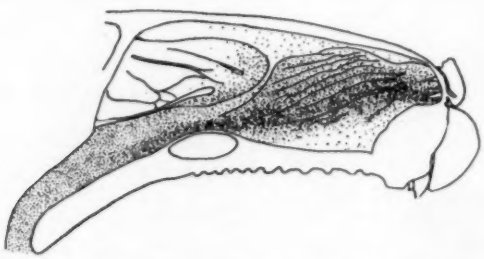

Fig. 8.—Illustration similar to figure 7, showing the lateral wall of the nasal fossa of the rabbit.

of air would conceivably be diverted also toward the floor, but a bulge in the base of the septum prevents this region from being as spacious as inspection of the lateral wall would suggest. Nevertheless, it was noted in rabbits required to breathe carbon-laden air that a large amount of material was deposited along the floor and lower border of the inferior concha.

The cat (fig. 9) illustrates still more definitely the tendency among the mammals to deflection of the incurrent air toward the floor. The

18. Marchand, F.: Beitrag zur Pathologie und pathologischen Anatomie des Bronchialasthma, mit Berücksichtigung der platischen Bronchitis und der Colica mucosa, Beitr. z. path. Anat. u. z. allg. Path. **61**:251, 1916.

19. Sternberg, H.: Beiträge zur Physiologie und Pathologie der Schleimhaut der Luftwege: I. Die Veränderungen der Nasenschleimhaut bei ausgeschalteter Nasenatmung, Ztschr. f. Hals-, Nasen- u. Ohrenh. **7**:432, 1924.

20. Hilding, A.: Experimental Surgery of the Nose and Sinuses: I. Changes in the Morphology of the Epithelium Following Variations in Ventilation, Arch. Otolaryng. **16**:9 (July) 1932.

anteriorly projecting laminae of the ethmoid and inferior conchae serve as vanes to catch and direct the air downward, and by this means the air is probably cleaned and warmed, and its humidity is increased. The filtering action is particularly evident when carbon-laden air is breathed by the living animal. In fact, it is so effective that in the cat practically no carbon reaches the olfactory area, which is contrary to the result obtained when rats and guinea-pigs are subjected to the same treatment. A smaller amount of air, judging by the iodine staining, follows the superior meatus of the nose up along the roof toward the olfactory area. It has been the subject of controversy whether the olfactory sulcus of man, which has a position corresponding to the superior meatus of other mammals, functions as a channel for air to the olfactory area. It probably does so function in mammals, but experiments have indicated that in man its functional significance as a transmitter of air is doubtful.

The rat and guinea-pig possess noses less efficient than the cat in preventing carbon suspended in air from reaching the olfactory epi-

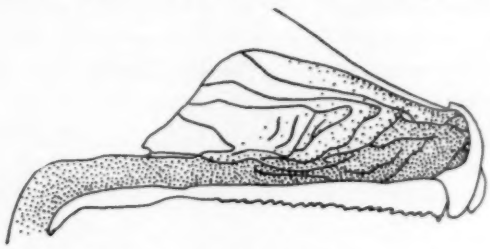

Fig. 9.—Illustration similar to figure 7, showing the lateral wall of the nasal fossa of the cat.

thelium. Breathing such air for ten minutes and sometimes less is sufficient, in these rodents, to lead to a large accumulation of dry carbon in the superior and posterior parts of this area. The dryness of the carbon heaped up here is in contrast to the well moistened particles held together by the strings of mucus in all other regions of the nose. This is probably due to the fact that the rolling action of the cilia-propelled mucous sheet described by Proetz [21] is lacking in the olfactory area.

Since carbon accumulates so readily in the olfactory region and because few or no cilia are known to be present in it, the mechanism of clearance, if it exists, was immediately sought.

In the first experiment two rats were required to breathe carbon-laden air for a length of time known to be sufficient for carbon to accumulate in the olfactory area and were killed seventeen and one-half

21. Proetz, A. W.: Physics and Physiology of Sinuses, Ann. Otol., Rhin. & Laryng. **38**:963 (Dec.) 1929.

hours later. The nose of one was completely cleared, except for two or three fine particles still present in the olfactory part of the superior concha. The nose of the other showed an accumulation of pus along the entrance to the middle meatus and continuing below the ethmoid concha into the nasopharynx. The olfactory area was completely cleared, but the nose had failed to clear itself of much of the carbon which had been held by the pus.

Another series of four rats was subjected to similar treatment. The animals were killed after four minutes, thirty minutes, one hour and two hours, respectively. The ciliated parts of the nose were fairly well cleaned at the end of one hour and completely so at the end of two hours, but the carbon in the olfactory area remained unchanged, except at the end of two hours, when there was a tendency for it to streak forward toward the region of ciliary pull on the mucous sheet.

The evidence would indicate that the factor of traction noted and described by Hilding [3b] as responsible for clearance across the stratified and transitional epithelium in the anterior parts of the nose may be the mechanism of clearance in the olfactory area as well—a conclusion that emphasizes the importance of the direction of beat of cilia limiting this nonciliated area.

It is evident from this investigation that in the noses of domestic and laboratory animals the air currents are deflected principally toward the inferior parts of the nose, while they arch upward in man and the monkey.

COMMENT

It is necessary to review the pattern of ciliary movement in the noses of man and the monkey to make clear the comparison with the pattern in the noses of other mammals. Figure 3 *A* is a diagram combining the recorded observations of Yates [2] and Hilding [3b] concerning the direction of mucous flow in the nose of man, and figure 3 *B* is from the earlier work of Lucas [1b] on Macacus rhesus.

In man the mucous flow is almost directly toward the nasopharynx. No suggestion of any inclination toward the anterior nares is apparent. All the mucus of the monkey's nose also ultimately reaches the nasopharynx, but in so doing it follows more devious paths. There is a tendency in the monkey (limited to the upper half of the nose and especially in the regions adjacent to the olfactory border) for the streams to start their movement toward the anterior nares. A still more pronounced inclination in an anterior direction is found in the cat, in which materials present on the superior concha and the middle meatus do reach the stratified epithelium at the anterior end of the nose. Mucus in the remaining regions of the cat's nose arrives in the nasopharynx. The other mammals examined, ranging in size from mouse to cow, all

showed a greater proportion of surface contributing mucus to the anterior end of the nose than the cat. In general, therefore, the pattern of ciliary movement in the domestic and laboratory mammals stands in contrast to the pattern in man and the monkey. It is reasonable to suppose that the difference is related to either functional expediency or structure, and all possible correlations should be considered which may indicate the *raison d'être* of the design.

Many data show that the activity of the cilia is most effective in the upper half of the nose in rodents, ruminants and the cat, a condition which likewise stands in contrast to that found in man and the monkey, where the regions of greater activity occur in the inferior part of the nose. This clearcut correlation between pattern and ciliary gradient does not, however, apparently indicate any causal relation. Both have developed in response to some third factor.

Structure per se should be considered as a possible agent which might shape the ciliary pattern. The ethmoid concha of the cat strikingly illustrates a certain degree of correlation between structure and pattern. This organ has extended anteriorly far beyond the limit found in other mammals and occupies territory usually filled by the inferior concha; yet, despite the translocation in relation to the nose as a whole, it has retained the ciliary pattern characteristic for this structure. In this connection, a variation of pattern sometimes observed, namely, one in which the streams in the anterior part of the ethmoid concha of some individuals fail to curve diagonally backward but move across the folds diagonally forward and downward, may have significance as contrary evidence of this correlation. Additional evidence that structure and ciliary pattern may not be correlated is apparent when the difference in pattern on the inferior concha of the monkey and the cow is considered in relation to the similarity in shape of their medial surfaces. Therefore, it is suggested that the shape and structure of the nasal cavity does not of itself determine the direction of drainage. Structure is a factor only so far as it governs the direction of air currents, which, as is now apparent, do have an effect on the ciliary pattern.

Gravity may conceivably be responsible for the flow of mucus toward the anterior end. A somewhat close correlation exists here. Man, more than any other animal, holds his head in a horizontal or nearly horizontal position a large part of the time. The monkey shows a slightly greater inclination of the nose downward, and one finds also a corresponding tendency of some streams to pass anteriorly before curving downward and backward. The cat, a carnivorous animal, spends much of its time walking or lying in wait, during which period the anteroposterior axis of the nose is held somewhere between a horizontal and a vertical position. Feeding, during which the axis approaches the

vertical position, occupies a relatively short part of the day. Thus, what might be called the normal position of the nose is intermediate between that of the monkey and that of the rodents and ruminants. The records of ciliary movement also reveal in the cat an intermediate pattern. The other animals—the rodents and ruminants—possess feeding habits that require that the nose be inclined toward the ground a large part of the day, and all show a greater tendency for the drainage of the nose to pass anteriorly. Yet, in spite of this apparent correlation, it is still doubtful whether gravity has any causal relation to the design of the ciliary pattern.

It seems much more probable that the air as it passes through the nose is the causal agent, because in every case the cilia are less efficient in the regions which carry the major portion of the inhaled air and more efficient in the parts of the nose protected from such abundant ventilation. It appears that even the burden of normal ventilation, when no pathologic conditions exist, is not conducive to maximum mucous passage.

The direction which inhaled air currents must follow is determined chiefly by the shape of the nose; and of special importance in this connection is the location and angle of the anterior nares to the cavity within. Evidence of this relationship is apparent in every animal studied.

In man the angle of the nares is such that air entering the nose curves upward and the internal structures do not act to any great extent as deflectors. The nares of the monkey are about the same as in man, but in this animal the infolded alae, the prominent tubercle of the septum and, particularly, the paddle-shaped inferior surface of the middle concha act to divert the air from its upward course. The noses of laboratory and domestic mammals are long and narrow compared with those of primates; the nares occupy a position close to the floor, and in addition the many laminae and folds all operate to direct the inhaled air along the floor and prevent little, if any, movement upward. Particularly important is the passive rôle played by the fossa of the middle meatus. It is toward this cavity, which is located on the lee side of the inhaled air, that the most vigorously propelled mucous streams converge. The fossa is particularly constructed to collect the mucus from the anterior and superior parts of the nose, and its narrow but mobile connection with the anterior nares provides an exit, which, by means of an explosive exhalation, effects the discharge of the accumulated mucus. The absence of such a protected pocket in the anterior end of the nose of man is the probable reason why no anteriorly directed streams exist. It is interesting to note that at the anterior end of the monkey's nose

there are a slight tendency toward the formation of such a fossa above the infolded ala and a corresponding slight anterior inclination of ciliary streams in the upper part of the nose.

SUMMARY

1. The mucus in the upper and anterior parts of the noses of the mouse, rat, rabbit, cat, cow and sheep drains toward the fossa of the middle meatus and toward the anterior nares. In the primates—man and the monkey—the entire mucous drainage is toward the nasopharynx.

2. The regions of most vigorous ciliary activity in laboratory and domestic mammals are in the upper parts of the nose and especially in the middle meatus. Poor ciliary movement or frequently none occurs in the inferior parts of the nose. The gradient of increasing activity from floor to roof is the reverse of that previously observed in the monkey, in which the slowest mucous flow occurs along the roof and the most rapid on the floor.

3. Inhaled air currents arch downward in the noses of laboratory and domestic mammals, in contrast to their upward curved path in man and the monkey.

4. It was concluded that the structure of the nose, particularly the position and angle of the anterior nares, is the chief agent in determining the path of air currents, and that the pattern of the air current, in turn, is the principal factor in determining the direction of ciliary pathways and the gradient of ciliary activity. It thus appears as a probable corollary that the normal passage of air is detrimental to maximum ciliary activity and mucous flow.

5. During the course of these investigations the following additional new facts were learned: (*a*) The difference in the rate of ciliary movement in different regions of the nose is not due to differences in the length of the cilia. (*b*) From 74 to 84 per cent of the surface area of the nasal mucosa in the region of the middle concha is ciliated; the remaining percentage is occupied by the openings of mixed glands and goblet cells. (*c*) The so-called mucous sheet is composed of two layers—an outer stratum of mucus, which rests on the tips of the moving cilia, and an inner fluid layer of low viscosity, which forms a suitable medium for the vibrating cilia.

CHRONIC ANTRUM INFECTION

TREATMENT BY INTRANASAL ANTRUM OPERATION AND PACKING; CLINICAL AND EXPERIMENTAL RESULTS

HENRY M. GOODYEAR, M.D.
CINCINNATI

Until six years ago I believed that an intranasal antrum operation was not to be considered in the treatment of chronic maxillary sinusitis. If an operation was warranted at all, no procedure short of a radical Caldwell-Luc operation would suffice, and to this principle I firmly adhered.

In September 1927, I became interested in the intranasal antrum operation and believed that perhaps I had been overlooking an important and helpful procedure in the treatment of chronically infected maxillary sinuses.

I do not mean to imply that the Caldwell-Luc operation can be safely and totally replaced by this more conservative procedure. However, my experience convinces me that in many cases the end-results in a properly performed intranasal operation are equal and even superior to those obtained by the more radical approach through the canine fossa. It is to be hoped that further study will make it possible to know when the intranasal operation will succeed and when only the approach through the canine fossa and exenteration will suffice.

What happens to a maxillary sinus after a so-called Caldwell-Luc operation? Does another normal membrane regenerate? According to present teachings the scar tissue is covered by a new ciliated epithelium. Then what difference is there between this healed sinus and the original sinus before infection, save for a large opening through the inferior meatus?

If this opening is the only difference from the original sinus it must represent the most important controlling factor as to reinfection and a second operation.

For many years in the teachings of the technic of the intranasal operation great stress has been laid on making the opening far anteriorly. To this end all sorts of anterior biting forceps have been devised with the purpose of cutting into thick heavy bone. At the same time surgeons have been cautioned against cutting too far posteriorly for fear of opening a branch of the sphenopalatine artery.

In my experience in a series of eighty-four operations during the past six years, I have found not only that it is important to extend

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the opening well anteriorly, but that it is far more important to extend it posteriorly where dependent drainage is obtained (fig. 1).

I do not hesitate to cut as far posteriorly as I have found possible with a straight downward cutting sphenoid forceps (fig. 2 *C*), and in this series of eighty-four cases there has been one hemorrhage, which occurred five days after the operation.

I have adopted the following definite procedure in the operation:

1. From thirty to forty minutes preceding the operation from 3 to 6 grains (0.195 to 0.4 Gm.) of sodium amytal or ortal sodium is given (if the patient is in the hospital a hypodermic injection of morphine or of a mixture of the hydrochlorides of the opium alkaloids is added).

2. Powdered cocaine and epinephrine are applied throughout the middle and inferior meatus and to the inferior turbinate.

3. A 1 per cent solution of a brand of procaine hydrochloride U.S.P. and epinephrine (usually 1 or 2 cc.) is injected into the anterior inferior turbinate and deeply in the skin and soft tissues. (Block anesthesia was also used in a few cases.)

4. The inferior turbinate is elevated with a Dunning submucus elevator.

5. A Bishop perforator is inserted well posteriorly and slightly upward, then rotated anteriorly. Through this first opening cocaine is applied on a bent applicator.

6. An anterior biting forcep on a universal handle is used to cut upward, downward and forward as far as possible, stopping only to apply cocaine as needed.

7. A straight downward cutting sphenoid forceps, perhaps the most important single instrument in the success of the operation, is used to cut backward as far as possible, rounding upward and downward, and lowering the floor. This instrument may also be used to advantage to cut forward.

8. A downward cutting forceps is used to lower the floor further.

9. Cocaine is again applied, and the floor and angles of the sinus are curetted with a Pratt curet and cleaned further with a nasal forceps.

10. The entire cavity of the antrum is packed with ½ inch (1.27 cm.) of 5 per cent iodoform gauze, and the packing is made to extend firmly into the new opening to prevent hemorrhage.

11. The inferior turbinate is replaced. The time consumed in the operation is about fifteen to twenty minutes.

Cold compresses and additional sedatives may be necessary during the first day. Usually the packing is not disturbed for from four to nine days; it may be removed gradually as it softens with secretion.

Most of the patients in this series were advised that a Caldwell-Luc operation was indicated; only when they refused this operation, or when they could not go to the hospital or remain away from work a sufficient time, was the intranasal operation performed.

With a few exceptions all these operations were performed in a treatment room at the office, and the patients went home immediately,

returning to all or a part of their accustomed duties within from one to three days. Many did not return to the office for the removal of the packing for from six to ten—usually seven—days.

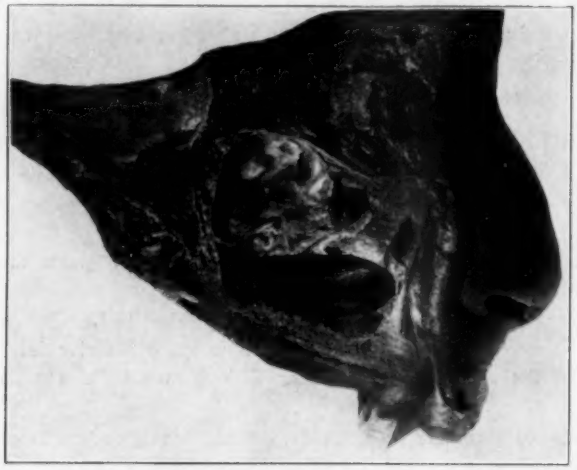

Fig. 1.—Note the large rounded opening extending far posteriorly.

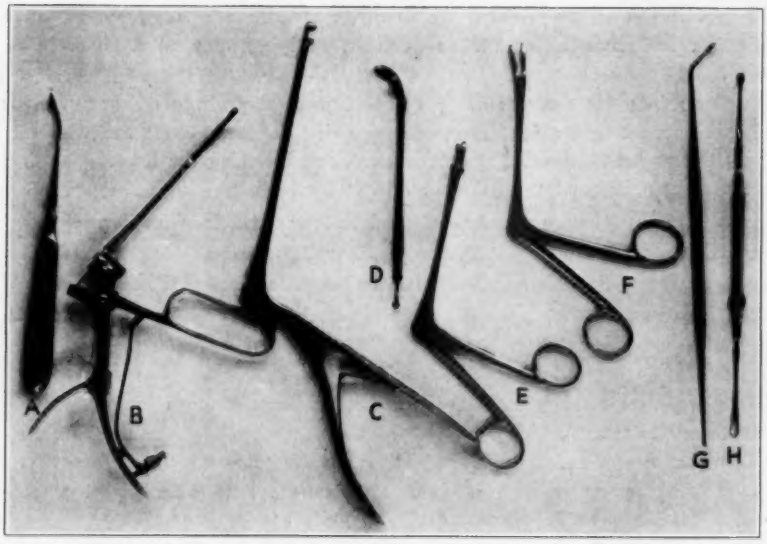

Fig. 2.—Instruments especially advised: *A*, Bishop perforator; *B*, anterior biting forceps; *C*, straight downward cutting sphenoid forceps; *D*, downward cutting forceps; *E*, straight cutting forceps; *F*, nasal forceps; *G*, Pratt curet; *H*, Dunning submucous elevator.

I believe that the packing is of importance, not only because it prevents hemorrhage, but because the rather prolonged pressure of the

gauze treated with iodoform against the diseased membrane is stimulating toward the regeneration of a normal membrane.

Solution of from 2 to 5 per cent silver nitrate was applied to the floor and walls of the sinus at intervals in a number of the cases, but few irrigations were used unless secretions were rather profuse.

Secondary enlargement of the opening was done in six cases and in one case, three times. In the latter case an outstanding good result followed the third operation. This fact emphasized the point that a good result can be obtained only when a large, well rounded opening is made.

Fig. 3 (Mrs. M. T., age 44).—Long, deep antrum at the time of the Caldwell-Luc operation and complete removal of membrane. Front view made six years after operation. The patient was symptom-free. Note the diminished size of the cavity.

In this series of cases I was particularly impressed with the fact that when only fair or poor results were obtained the opening was usually correspondingly bad.

After many so-called Caldwell-Luc operations, one finds on intranasal examination that the antrum cavity has been so reduced in size that one immediately wonders whether the opening made into the inferior meatus has closed, when, as a matter of fact, the cavity has only filled with a thick fibrous tissue (figs. 3 and 4). This tissue is apparently not readily reinfected. However, pockets and reinfections do occur. Recently I performed a Caldwell-Luc operation on a patient

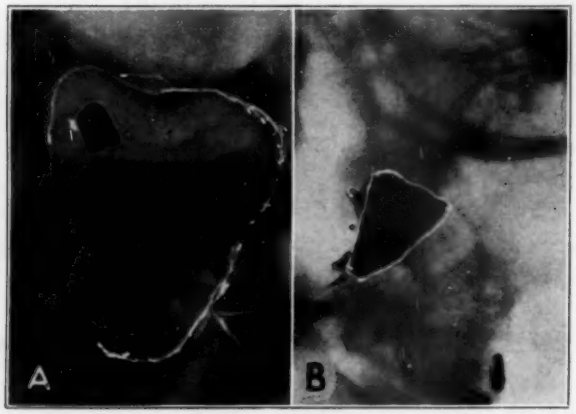

Fig. 4 (Mr. R. C., age 33).—Large antrum at the time of the Caldwell-Luc operation and complete removal of the membrane. *A* and *B*, front and side views four years after operation. Note that the cavity is almost obliterated by fibrous tissue. The patient was symptom-free.

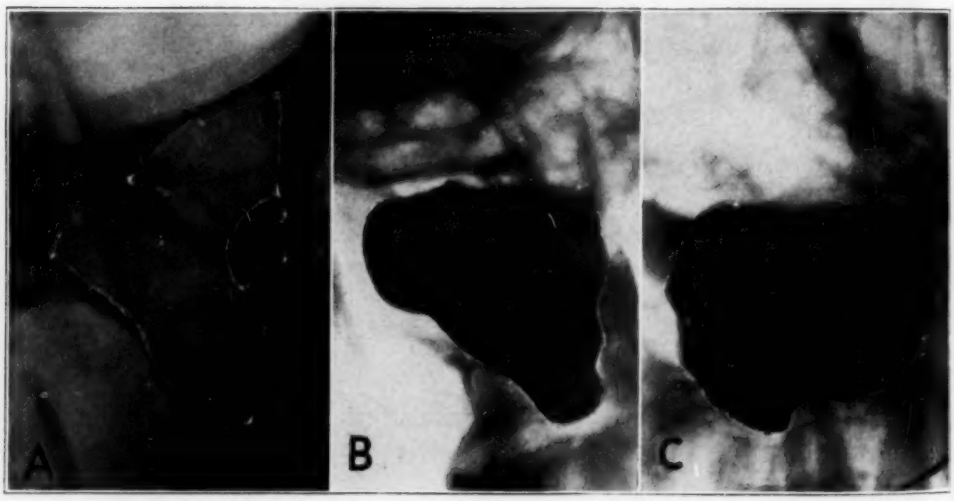

Fig. 5 (Miss B. D., age 31).—The patient had had chronic suppuration for six years. *A*, appearance before operation, with a small globule of the opaque oil injected and the remainder of the antrum filled with hyperplastic tissue; *B* and *C*, front and side views six months after intranasal operation. Opening blocked by wet gauze, and cavity filled with opaque oil. Note the excellent filling. The patient stated that five or six handkerchiefs were necessary daily before operation. At present no abnormal secretion is noted, and the walls of the cavity appear smooth and firm.

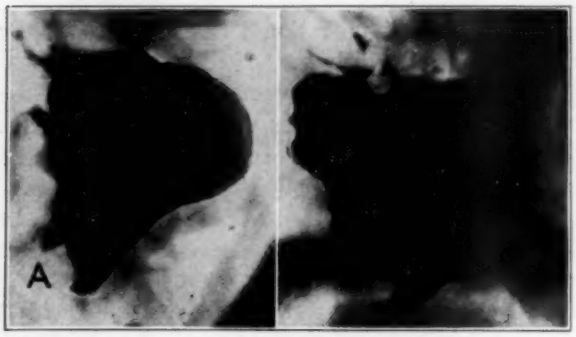

Fig. 6 (Mr. D. A., age 58).—The antrum had been infected for several years, following an infection of an upper molar, which had been extracted without relief. Repeated irrigations for ten weeks persistently showed foul pus. The patient refused an opening through the canine fossa. Two months after the intranasal operation the antrum was dry and the patient had gained 10 pounds (4.5 Kg.). *A* and *B*, front and side views more than six years after the operation during which time there has been no recurrence of the infection.

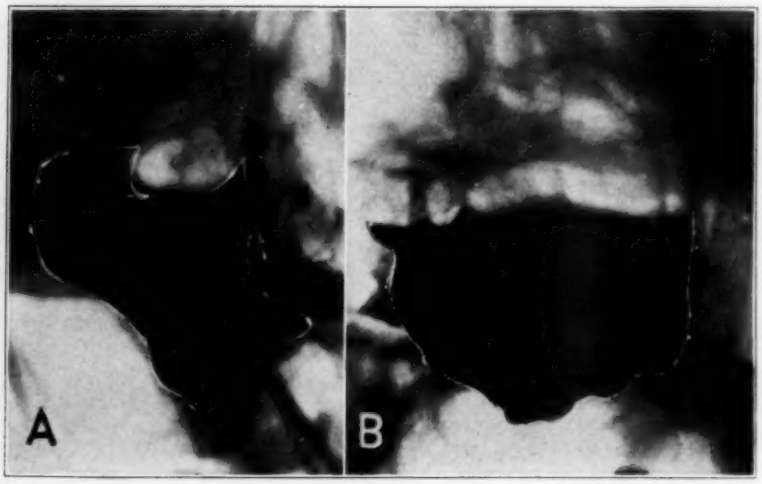

Fig. 7 (Mrs. W. R., age 42).—The patient suffered from cough and general decline in health; there had been a large dental antrum fistula for one year; the antrum was completely filled with hyperplastic tissue. *A* and *B*, front and side views, two years after intranasal operation and curettage of the fistula. The patient was symptom-free.

who had had a similar operation twice before by excellent surgeons, who had also exenterated the ethmoid cells thoroughly.

Following the intranasal operation I have not been able to find any cases in which this extreme thickening of tissue occurs, probably because the lining membrane has not been removed. Usually, if results were obtained at all, even though the sinus was completely filled with hyperplastic tissue at operation, the hyperplasia largely disappeared and a fairly normal filling cavity resulted (figs. 5, 6 and 7).

In most of my cases no great effort was made to remove the lining membrane or excess tissue, and, in some cases, for experimental reasons, no tissue was removed at all beyond the opening. To my surprise some months later the cavities were free from any evident secretion, and the walls were smooth and firm (figs. 5, 6 and 7), apparently all that could be desired following any type of operation on the sinus.

556 Doctors' Building.

ORGANIC FOREIGN BODIES IN THE BRONCHI

REACTION OF LUNG TISSUE IN RABBITS

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LOS ANGELES

The normal protective mechanism of the lower respiratory tract consists of the (1) mucous secretion, (2) ciliary action, (3) cough reflex and (4) phagocytosis.

PROTECTIVE MECHANISM OF THE TRACHEA AND BRONCHI

Mucous Secretion.—There are two sets of glands producing mucus in the trachea and bronchi: (*a*) the goblet cells which are distributed in the mucosa, being more numerous in the larger bronchi than in the trachea, but diminishing in number as the bronchi diminish in diameter and finally disappearing in the bronchioli 0.4 mm. in diameter [1] and (*b*) the acini of the secretory glands within the tunica propria, which are serous, mucous or mixed. The rate, quality and quantity of secretion appear to be vastly different under varying conditions. Hill [2] showed, on the excised trachea, that mucous secretion evidences a remarkable power to enmesh small foreign bodies. Larsell [3] noted that the stimulation of the secretory nerves activated the tracheal glands. Prolonged stimulation led to exhaustion. There was no evidence to indicate that the goblet cells could be discharged by stimulation of the nerves. Florey [4] and his associates showed that when a small drop of graphite ink suspended in physiologic solution of sodium chloride was applied to the tracheal mucosa the particular matter adhered to the strands of mucus as they were being propelled upward. Some of the particles sank and tended to stay or, at least, were moved slowly upward until they were caught on the strands of mucus. When a dry

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This study was conducted with the cooperation of B. N. Colver, M.D., College of Medical Evangelists.

This report is Part III of a thesis submitted to the Faculty of Otolaryngology of the Graduate School of Medicine of the University of Pennsylvania in partial fulfilment of the requirements for the degree of Doctor of Medical Science for graduate work in otolaryngology.

1. Miller, William Snow, in Cowdry, E. V.: Special Cytology, New York, Paul B. Hoeber, Inc., 1928, vol. 1, p. 72.

2. Hill, Leonard: Ciliary Movement of the Trachea, Lancet **2**:802 (Oct. 20) 1928.

3. Larsell, O.: The Ganglia, Plexuses, and Nerve-Terminations of the Mammalian Lung and Pleura Pulmonalis, J. Comp. Neurol. **35**:97, 1922.

4. Florey, H.; Carleton, H. M., and Wells, A. Q.: Mucus Secretion in the Trachea, Brit. J. Exper. Path. **13**:169 (June) 1932.

substance was placed on the mucosa it was necessary for it to be thoroughly moistened by secretion before it was carried away. A striking feature in their experiments was the ease with which the surface of the trachea could produce fluid without any significant intervention on the part of the glands. Another interesting observation was that cells and acini, which on a purely histologic basis would be called serous, may under certain circumstances secrete mucus.

Ciliary Action.—The mucous membrane of the trachea and bronchi is supplied with ciliated columnar epithelium, interspersed with goblet cells. A hundred years ago Sharpey [5] showed that by immersing a piece of trachea in tepid water and using charcoal as an index, the current of ciliary movement in mammals and birds was toward the larynx. Proetz [6] stated that cilia do not propel foreign bodies by direct contact with them, but by their concerted wavelike action propel the viscid blanket of mucus in which the foreign particles are caught. This propulsion goes on at great speed, many times the length of the cilium per second. This rapid, powerful and coordinating wavelike action adds greatly to the effectiveness of the defense mechanism. According to Howell [7] an area of 1 sq. cm. is capable of moving a load of 336 Gm. The contractions are automatic. The influence of the sympathetic nervous system has been suggested, but the mechanism is still disputed. The ciliary movement is affected by variation in temperature and the reaction of the surrounding medium. Cilia appear to behave differently toward different drugs sprayed on the mucus. They show a remarkable capacity to withstand assaults, and when injured they regenerate rapidly. It is reasonable to assume that the mucous secretion and ciliary action are interdependent and supplementary in their rôles in removing foreign materials.

Cough Reflex.—When comparatively large foreign bodies, such as are studied here, come in contact with the mucous membrane, the most potent protective mechanism is the cough reflex, the physiologic function of which has long been recognized. The efficacy of the cough reflex is shown by the fact that in more than 500 animals examined post mortem, in our research, only 160 actually retained foreign bodies within the lower part of their air passages at the end of the twenty-four to ninety-six hour periods. Failure to control the cough reflex has heretofore prevented investigators from conducting, on a large scale, experimental bronchoscopic studies with solid foreign bodies. Before the days of

5. Sharpey, W.: Cilia, in Todd, R. B.: Cyclopaedia of Anatomy and Physiology, London, Longmans, 1835; quoted by Florey.

6. Proetz, Arthur W.: Some Intimate Studies of Nasal Function; Their Bearing on Diagnosis and Treatment, Ann. Otol., Rhin. & Laryng. **41**:125 (March) 1932; Five Preliminary Notes on Nasal Function, ibid. **41**:1117 (Dec.) 1932.

7. Howell, W. H.: Textbook on Physiology, ed. 12, Philadelphia, W. B. Saunders Company, 1933, p. 64.

bronchoscopy, Mendelssohn,[8] in 1844, produced atelectasis by obstructing the bronchi with shot, paper and acacia solution. This was followed, in 1846, by the observations of Traube[9] and others. Lee, Tucker and Clerf[10] were perhaps the first successful investigators; they removed secretion in a case of postoperative massive atelectasis and produced atelectasis in a dog by introducing 7 cc. of this fluid through a bronchoscope. Undoubtedly much of their success depended on their ability to control the cough reflex.

Phagocytosis.—Downey[11] defined phagocytosis as a physiologic process which is not confined to any one type of cell. He showed that the material, which under ordinary conditions would be taken up only by a certain type of cell, may under slightly different conditions be taken up by cells which genetically and structurally are distinct from the first type. According to Aschoff,[12] Kiyono[13] and others, phagocytosis is different from vital coloring, which is a special case of colloidopexy. Shuleman[14] pointed out a difference between the two processes, phagocytosis being the absorption of microscopic particles and colloidopexy the absorption of ultramicroscopic particles, leading first to a suspension of particles within the protoplasm and then to a condensation around these primitive droplets. No matter what the process of colloidopexy may be it often does not coexist with phagocytosis. The highly dispersed colloid dyes give first a diffuse coloring while the suspensoids are directly subjected to phagocytosis.

Fried[15] stated that the original conception of Metchnikoff, who attributed to the macrophage only defensive potentialities, has recently been immensely broadened. Today one attributes to the mesenchyme, and particularly to the macrophage, a dominating rôle in the formation of bile and also in the metabolism of various substances such as water, lipoids, iron and cholesterol. The connective tissue is believed to be

8. Mendelssohn, A., quoted by Lord, F. F.: Diseases of the Bronchi, Lungs, and Pleura, Philadelphia, Lea & Febiger, 1915.

9. Traube, L.: Beitr. z. exper. Path. u. Physiol. **1**:65, 1846.

10. Lee, W. C.; Tucker, G., and Clerf, L. A.: Postoperative Pulmonary Atelectasis, Ann. Surg. **38**:6, 1928.

11. Downey, Hal: Histocytes and Macrophages and Their Relations to the Cells of Normal Blood in Animals Stained Intra Vitam with Acid Colloidal Dyes, Anat. Rec. **2**:6 (Jan.) 1917.

12. Aschoff, L.: Das Reticulo-endotheliale System, Ergebn. d. inn. Med. u. Kinderh. **26**:1, 1924.

13. Kiyono, K.: The Present Status of Vital Staining and Its Methods, Jap. ed., Tokyo, Nankodo, 1920.

14. Shuleman, quoted by Bratiano, L., and Guerriero, C.: Sur la fonction de colloïdopexie (ultraphagocytose) et le pouvoir phagocytaire des elements cellulaires du poumon des oiseaux, Compt. rend. Soc. de biol. **104**:87 (May 9) 1930.

15. Fried, B. M.: Defensive and Metabolic Apparatus of the Lungs; The Lungs and the Macrophage System, Arch. Path. **6**:1008 (Dec.) 1928.

not only a "frame," that is, a silent supporting substance, but an "organ" endowed with various highly differentiated functions and, analogous to glands, possessing possibly the properties of internal secretion.

I do not propose to enter into an academic discussion of the origin of the alveolar phagocytes, a discussion too far afield from the present study. In the literature one may consult the articles of Sewell,[16] Guieysse-Pellissier,[17] Permar,[18] Foot,[19] Stewart,[20] Carleton,[21] Wislocki,[22] Fried,[23] Lewis,[24] Lang,[25] Maximow,[26] Gardner and Smith,[27] Duthie,[28]

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Francescon,[29] Ropes,[30] Vallone,[31] Mathis,[32] Platonow,[33] Borghesan [34] and many others. In passing, it may be stated that many of these workers are in total disagreement as to the origin of alveolar phagocytes. In brief they are divided into four schools of thought: those who consider that alveolar phagocytes originate (1) from the alveolar lining, (2) from the blood stream, (3) from specialized histiocytes and (4) from the vascular endothelium. Boyd [35] summarized the views accepted by the majority of pathologists in the following statement: "It seems that the weight of opinion is tipping the scale in the favor of the monocyte as the parent of the dust cell."

The principal phagocytic cells are histiocytes, fibroblasts, monocytes, polymorphonuclear leukocytes and lymphocytes. Pioneer investigation in phagocytosis of pulmonary cells by the method of vital staining was carried on by Goldmann.[36] This was followed by the work of Mashima,[37] who combined the method of intratracheal introduction of a foreign body with vital staining. The Japanese introduced talcum suspended in physiologic solution of sodium chloride into the tracheobronchial system, after which the animals were killed and the lung tissue was impregnated with solution of silver nitrate.

In recent years the metabolic function of the pulmonary parenchyma has been studied. Some support the theory that alkaloids and various other toxic substances are oxidized in the lung tissue. It is stated also that lungs play a part in the metabolism of fat and sugar. Just what part this phase of the pulmonary function plays as a defensive mechanism needs further elucidation before it can be accepted as one of the pluripotentialities of the lungs.

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OBJECT OF EXPERIMENT

The reaction of pulmonary tissue in the presence of foreign bodies depends on several factors: (1) the character, size and shape of the object; (2) the manner and degree of intrabronchial obstruction, and (3) the duration of the sojourn.

The experimental work herein reported constitutes a unique method of study of the cellular reaction in the lungs. Heretofore only fluids or semisolids were employed, and these were introduced (*a*) by intratracheal injection, (*b*) through a tracheotomy wound, and, more recently, (*c*) through a bronchoscope. As far as I am aware, this is the first report of the introduction of comparatively large-sized solid bodies through the normal orifice by means of peroral endoscopy. I believe that such an approach opens a new field of research. A knowledge of the histopathology in these cases is most desirable. Such knowledge aids the bronchoscopist to analyze intelligently the clinical symptoms present.

TECHNIC OF OPERATION

Young rabbits, weighing from 1.3 to 1.8 Kg. (from 3 to 3½ pounds) were best suited for the purpose. Only those which were active and free from respiratory infection were used. Titrated and sterilized solution of amytal was injected intraperitoneally for anesthesia. The average dose was from 45 to 50 mg. per kilogram of body weight. There was considerable variation in the tolerance of the individual animal to the drug. Rarely two and never more than three injections were required for complete narcosis. An operating table specially constructed for endoscopic purposes was used. The assistant supported the animal's head in the usual manner for man.

Two instruments were specially constructed. One was a laryngoscope, measuring 4 mm. by 16 cm. similar to Jackson's infant bronchoscope. The other was a pair of forceps, similar to Jackson's forward grasping type, 25 cm. in length (fig. 1). The forceps was used for swabbing the lining of the larynx, trachea and bronchi with the anesthetic solution and for the introduction of the foreign bodies. With this improvised laryngoscope the tip of the epiglottis was lifted and the interior of the larynx was well exposed. The forceps readily passed beyond the carina into the terminal branches of the bronchi. In order to reduce the ever-present cough reflex, a 2 per cent aqueous solution of butyn was repeatedly applied over the carina and the lower air passages. When the tip of the laryngoscope reached the base of the tongue there were usually repeated blasts of coughing. This was soon followed by a period of quiescence, accompanied by deep respirations, which permitted the operative manipulation without further struggle. With a fair degree of care and practice the laryngeal orifice was easily exposed. After the animal was sufficiently narcotized the glottic opening was ample for the introduction of the object. The foreign body was grasped in the forceps and inserted under visual guidance without traumatizing the lining of the air passage. On a few occasions, when the animals struggled and caused much hemorrhage from the laryngeal mucosa, they were discarded.

Ten different organic foreign bodies were selected for the experiments: (1) peanuts, (2) pop-corn, the barks of (3) pepper and (4) eucalyptus trees and the seeds of (5) grapes, (6) oranges, (7) lemons, (8) grapefruit, (9) watermelon

and (10) cantaloupes. These are the foreign bodies most frequently encountered in Southern California. They were sufficiently small not to obstruct the primary bronchi and were uniform in size and shape when introduced.

The animals were kept in a warm room following the surgical manipulation just described. When recovered from the anesthesia they were transferred to cages and were kept under observation for twenty-four, forty-eight, seventy-two and ninety-six hours, at the end of which time they were killed and a necropsy performed. The chest was opened and the entire contents removed from the thorax. The posterior wall of the trachea and bronchi was opened longitudinally for inspection. Animals failing to show the presence of a foreign body were discarded. The experiments continued until 4 animals, with foreign bodies in the air passages for each of the four periods mentioned, were obtained. About two thirds of the animals used were without foreign bodies at the time of autopsy, thus necessitating the study of more than 500 animals in order to secure the 160 retaining foreign bodies at the time of autopsy. Sections of lung next to which the foreign body

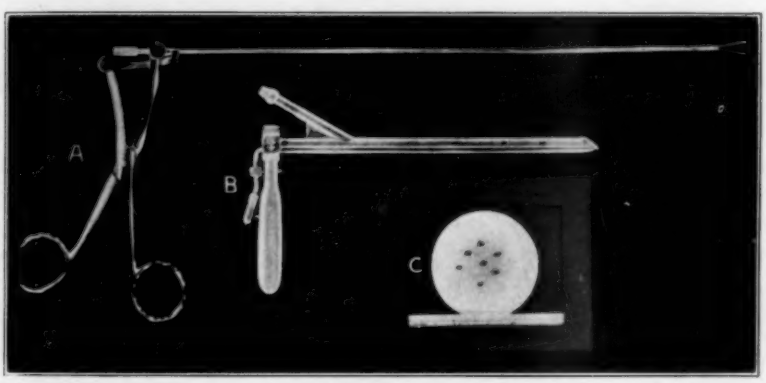

Fig. 1.—*A*, specially constructed forward grasping forceps. *B*, specially constructed laryngoscope. *C*, specimens of foreign bodies implanted.

was found were cut serially at from 6 to 8 microns in horizontal planes. The first sections were stained with hematoxylin and eosin and a second series with Maximow's solution. Sections from the trachea were treated in a similar manner.

POSTMORTEM OBSERVATION OF THE LUNGS

The gross appearance of the lungs varied considerably according to the objects introduced, the manner of the bronchial obstruction and the length of time which elapsed before the animal was killed.

In the twenty-four hour specimens the lungs containing cantaloupe seed or bark of the eucalyptus tree showed no obvious evidence of deviation from the normal when the air passage, before its division into the primary bronchi, was not completely occluded. Occasionally there were a few areas of petechial hemorrhage seen on the visceral surface of both lungs, more pronounced on the posterior aspects. In these the cut surface was pale pink, interspersed with small peribronchial areas

of exudation no larger than the point of a pencil. On pressure a varying amount of frothy fluid exuded. In the forty-eight and seventy-two hour specimens the foreign objects were coated with varying amounts of pus, but in the gross appearance of the lung there was only slight change. In one of the seventy-two hour specimens (no. 302) both lungs were so normal that we were surprised to find the foreign body at the carina. After ninety-six hours the lung appeared somewhat mottled, an evidence of alveolar congestion and exudation. When placed in water the specimen floated.

Lungs containing the seeds of citrous fruits, grape and watermelon showed a much greater reaction. These objects were invariably coated with brownish or grayish pus. At the end of twenty-four and forty-eight hours there were already a sufficient number of areas of consolidation to cause the lungs to appear mottled. The cut surface was soft, but much more congested than in the lungs containing canteloupe seed or bark of the eucalyptus tree. Each succeeding day brought a slightly more advanced reaction.

The greatest reactions, in the order of intensity, were noted in lungs containing peanuts, bark of the pepper tree and pop-corn. At the end of twenty-four hours the lungs containing these foreign bodies showed intense congestion and alternate areas of consolidation and emphysema. There was always much pus about the foreign body. The cut surface of the lung was firm, and bronchioles contained varying amounts of purulent exudate. There was, however, a sufficient quantity of air left within the alveoli to enable the lungs to float in water. With each succeeding day there were increasing areas of consolidation toward the periphery. Many were deep red to deep purplish, not unlike liver. The texture was firm and friable. The lobes were so tense and edematous that on several occasions some of them became detached from the main structure during the manipulation. The lungs showing these advanced changes invariably sank in water.

HISTOPATHOLOGIC OBSERVATIONS

Peanuts.—In the twenty-four hour specimens there were small amounts of exudate within the bronchi. This exudate was composed of many large mononuclear and a few polymorphonuclear leukocytes, erythrocytes and débris. The bronchial epithelial cells appeared to be fairly even; occasionally they were swollen and vacuolated. There were a few polymorphonuclear leukocytes and numerous large mononuclear leukocytes in the tunica propria. The pulmonary field, next to the bronchus, showed a heavy cellular exudate containing numerous large mononuclear leukocytes and a few polymorphonuclear leukocytes. Reticulo-endothelial cell hyperplasia developed early in the peribronchial lymph follicles. While the bronchial wall, in relation to this area, gave the impression of protruding into the lumen of the bronchus, the characteristic picture was that of an active large monocytic reaction in response to the presence of the foreign body (fig. 2).

In the forty-eight hour specimens there appeared progressive hyperplasia of the large mononuclear leukocytes in both the bronchial and the pulmonary structures. Hemorrhagic areas were scattered through the bronchial mucosa and alveoli. The bronchial epithelium tended to be increasingly swollen, taking a poorer stain, and some cells were cast off into the lumen. The alveolar walls were edematous in the immediate neighborhood of the larger bronchi, and the area of exudation was progressively widening. There was a definite proliferation of the endothelium of the blood vessel wall.

In the seventy-two hour series there appeared a considerable accummulation of polymorphonuclear leukocytes on the surface of the bronchial mucosa. The leukocytic infiltration was also noted in the tunica propria and throughout the deeper bronchial structure. An increasingly wider area of exudation appeared in the pulmonary field. This exudate consisted of a larger number of polymorpho-

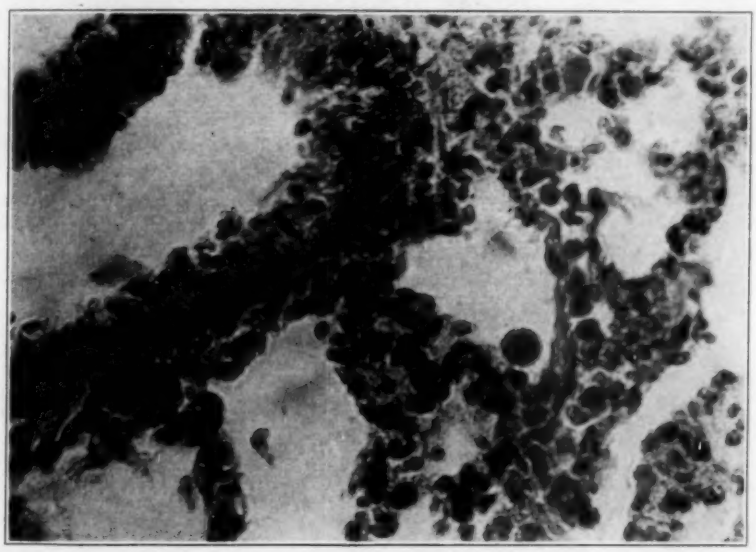

Fig. 2.—A section of rabbit's lung following endoscopic implantation of peanuts in the bronchus of the right lower lobe for twenty-four hours. The alveoli next to the bronchus shows a heavy cellular exudate containing numerous large mononuclear and a few polymorphonuclear leukocytes. The septal walls are many times thicker than normal; the proliferating cells are predominatingly large mononuclear cells. The bronchial epithelial cells are swollen and edematous; some of them are beginning to desquamate; × 420.

nuclear leukocytes than the twenty-four and forty-eight hour series and filled the alveoli. The most interesting feature noted in this series was a consistent and progressive endothelial cell proliferation of the smaller vessels of the obliterating type, resulting in an early infarct of the perivascular region (fig. 3).

In the ninety-six hour series the bronchial exudate appeared to undergo gradual disintegration. The surface epithelium was denuded in several areas, and an increasing number of polymorphonuclear leukocytes invaded the submucosa. Several areas of focal necrosis appeared in the lung tissue; the alveoli were filled with a large number of cast-off epithelial cells mixed with polymorphonuclear

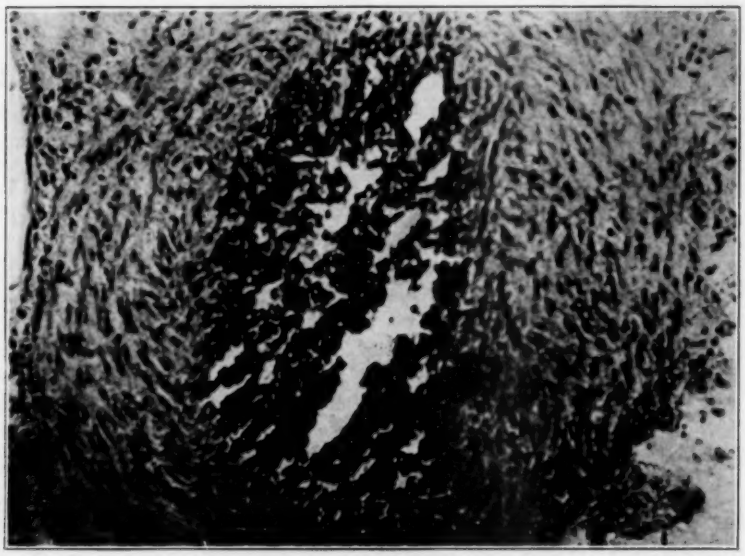

Fig. 3.—A section of small artery in rabbit's lung following endoscopic implantation of peanuts in the bronchus of the right lower lobe for seventy-two hours. The endothelial lining indicates marked proliferation, and its lumen is nearly occluded. The wall of the vessel is swollen and edematous and its entire thickness is infiltrated by numerous polymorphonuclear leukocytes; × 250.

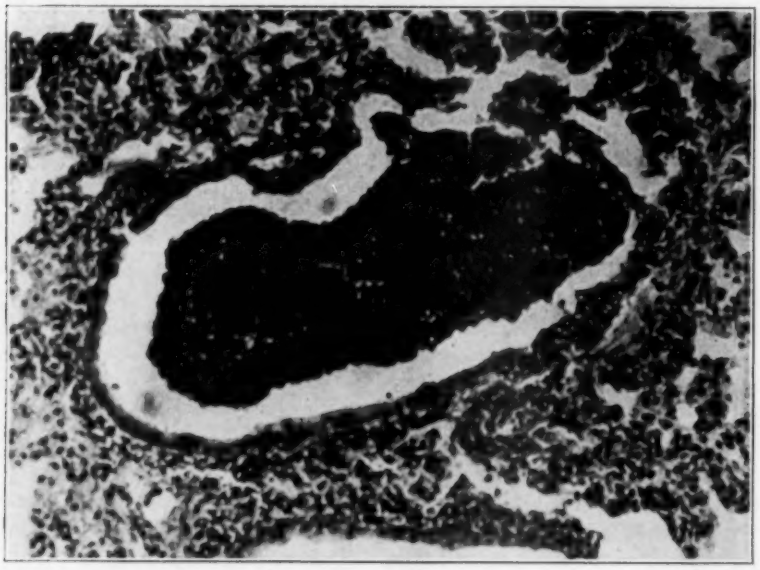

Fig. 4.—A section of rabbit's lung following endoscopic implantation of peanuts in the bronchus of the left lower lobe for ninety-six hours. The bronchial exudate is beginning to show gradual disintegration. The surface epithelial cells are denuded in several places, and a large number of polymorphonuclear leukocytes are infiltrating the deeper structures. The alveoli have lost their normal architecture owing to an accumulation of exudate which is producing early bronchopneumonia; × 250.

leukocytes, erythrocytes and large mononuclear leukocytes (fig. 4). The walls of the blood vessels in the region of the terminal bronchioles showed complete occlusion, and a well developed infarct was noted throughout the pulmonary field. In contrast with the previous series, though the number of polymorphonuclear leukocytes was noticeably increased, the characteristic picture was that of an intense reticuloendothelial cell proliferation, edema of the alveoli, intra-alveolar hemorrhage, progressive widening of the area of exudation and localized pneumonitis, with a tendency to rapid disintegration and necrosis spreading toward the periphery of the lung (fig. 5). Similar changes in the tissue were noted in the opposite lung which contained no foreign body.

Pop-Corn.—In the twenty-four and forty-eight hour specimens there was little bronchial exudate. The epithelial lining of the bronchioles remained intact. The

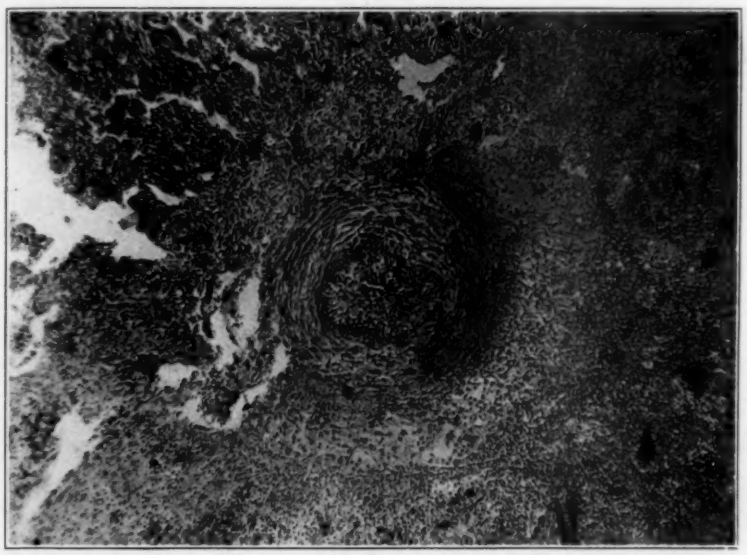

Fig. 5.—A section of rabbit's lung following endoscopic implantation of peanuts in the bronchus of the right lower lobe for ninety-six hours. The areas of exudation and localized pneumonitis are progressively widening. The endothelial lining of the blood vessel indicates marked proliferation, leading successively to obliterating arteritis, infarction and perivascular necrosis of the pulmonary parenchyma; × 90.

lymph follicles indicated progressively increasing reticulo-endothelial cell hyperplasia. There were scattered areas of hemorrhage within the walls of the alveoli as well as in the air spaces. Only a few polymorphonuclear leukocytes were noted in the lung field. No vascular changes were observed in these periods.

In the seventy-two and ninety-six hour series there was a gradual accumulation of bronchial exudate consisting of cast-off epithelium, mononuclear leukocytes, a few erythrocytes, scattered polymorphonuclear leukocytes and débris. The areas of exudation were confined to a small portion of the lung field around the larger bronchi. Beneath the exudate the bronchial epithelium appeared to be somewhat swollen and took the stain poorly. There was an intense reticulo-endothelial cell

hyperplasia reaction in the lymph follicles, and some of these appeared to break into the lumen of the bronchi. At this stage there was a perceptible increase in the endothelial cell proliferation of the larger blood vessels, but not sufficient to cause complete occlusion as seen in peanut bronchitis. The entire picture was that of marked initial proliferation by reticulo-endothelial cells which was giving way with each succeeding day to a progressive polymorphonuclear cell response probably due to secondary septic changes (fig. 6).

Bark of the Pepper Tree.—At the end of twenty-four hours the characteristic feature of bronchitis caused by the bark of the pepper tree was the edema of the peribronchial structure and the alveolar wall. The lymph follicles were swollen and large, and the surrounding areas were infiltrated by small mononuclear leukocytes. In the forty-eight hour specimens the bronchial exudate continued to

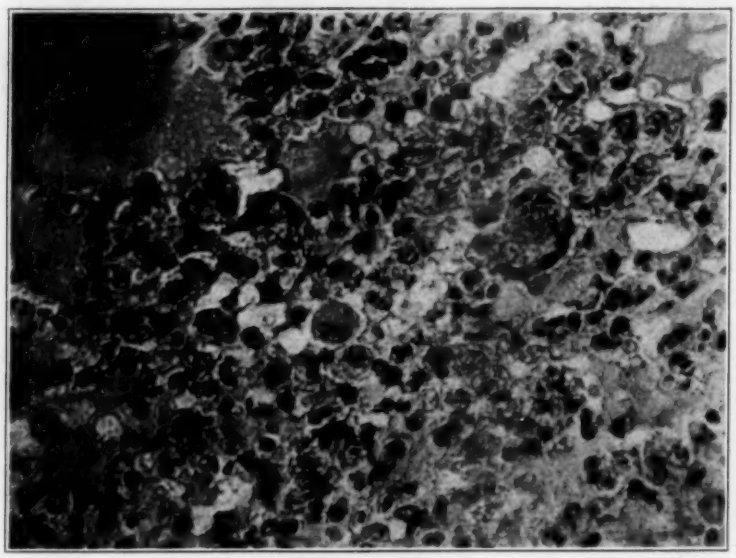

Fig. 6.—A section of rabbit's lung following endoscopic implantation of popcorn in the bronchus of the right lower lobe for ninety-six hours. Large mononuclear cells are seen proliferating in the alveolar wall. The alveoli are filled with exudate consisting of a large number of mononuclear wandering cells, a few polymorphonuclear leukocytes and erythrocytes. The area of exudation was limited at first to the larger bronchi and gradually expanded toward the periphery; × 420.

accumulate in large amounts. There was an increasing amount of edema in the alveolar wall. In the seventy-two hour specimens the bronchial exudate contained an increasing number of polymorphonuclear leukocytes and fewer large mononuclear leukocytes than on the previous days (fig. 7).

In ninety-six hours a portion of the bronchial epithelium began to be denuded. The area of exudation widened progressively. The alveolar wall showed intense proliferation by reticulo-endothelial cells. There was the beginning of an obliterating endothelial cell reaction of the smaller blood vessels at this stage.

Bark of the Eucalyptus Tree.—In contrast to the bark of the pepper tree the bark of the eucalyptus tree appeared to be only mildly irritating to the bronchial mucosa. The area with which the foreign body came in direct contact was denuded of the bronchial mucosa, but there was only a slight cellular response. At the end of forty-eight and seventy-two hours no bronchial exudate appeared and only a slight amount at the end of ninety-six hours in the larger bronchi. There was an early and persistent reaction of reticulo-endothelial cells in the peribronchial lymph follicles. The pulmonary field in the immediate neighborhood of the larger bronchi contained exudate composed chiefly of mononuclear wandering cells. Hemorrhage was profuse in the alveolar wall as well as in the alveolar spaces. But few polymorphonuclear leukocytes were present, and there were no vascular changes (fig. 8).

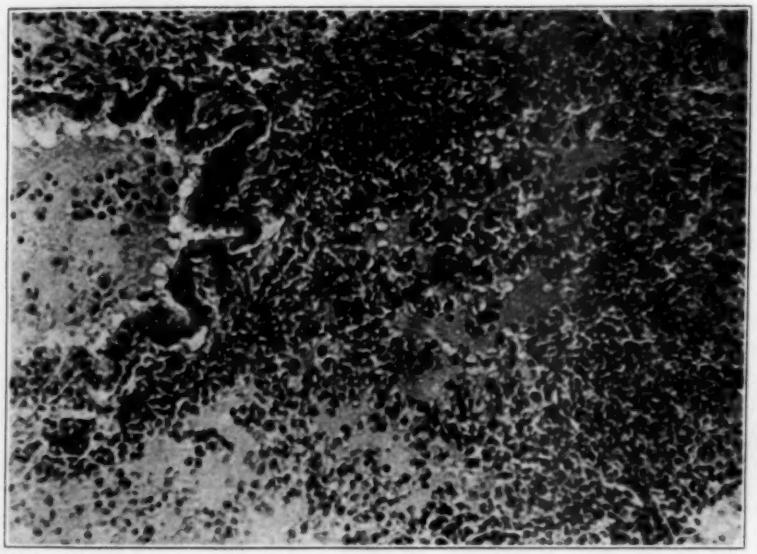

Fig. 7.—A section of rabbit's lung following endoscopic implantation of pepper tree bark in the bronchus of the left lower lobe for seventy-two hours. The bronchial lumen contains numerous polymorphonuclear leukocytes and a few large mononuclear cells. The lighter portion in the center of the photograph indicates the area of edema which was most marked in the peribronchial region. The area of early localized pneumonitis is shown next to the bronchus; × 250.

Grape Seed.—In the twenty-four hour series there was an early and persistent bronchial exudate consisting of polymorphonuclear leukocytes, erythrocytes and numerous mononuclear wandering cells. The foreign body was thickly coated with pus which completely obstructed the terminal branch of the bronchus. In the immediate neighborhood of the occluded bronchus and tributary bronchioles below was a limited area of exudation in which were many large mononuclear leukocytes, a few polymorphonuclear leukocytes, some cast-off epithelial cells, erythrocytes and débris.

In the forty-eight hour series there was involvement of a larger number of bronchioles and smaller bronchi. The area of exudate gradually widened.

In the seventy-two and ninety-six hour series this process was much increased. At the end of the fourth day a proliferation of the intima of the smaller arteries was noted. There was a moderate amount of edema in the alveoli. Of particular interest in grape seed bronchitis was the intense reaction of the reticulo-endothelial cells and the tendency to the formation of large multinucleated cells. These multinucleated cells were probably precursors of giant cells. The absence of hemorrhage in the alveolar wall or in the alveoli was another interesting observation.

Orange and Lemon Seeds.—The seeds of oranges and lemons caused a comparatively mild cellular reaction. Twenty-four hour specimens with orange seed showed no bronchial exudate. There were varying degrees of hemorrhage in the alveolar wall. An increasing number of reticulo-endothelial cells in the alveolar wall appeared each succeeding day. There were more large mononuclear than

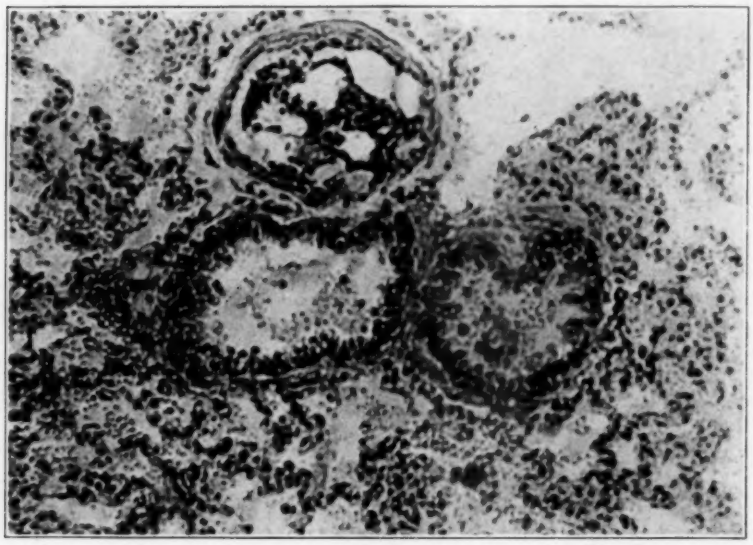

Fig. 8.—A section of rabbit's lung following endoscopic implantation of bark of the eucalyptus tree in the bronchus of the right lower lobe for ninety-six hours. The bronchial epithelial cells are swollen and desquamating in several places. The bronchial exudate consists of numerous erythrocytes, a few large mononuclear wandering cells and cast-off epithelial cells. Polymorphonuclear leukocytes are practically absent. Of particular interest is the profuse hemorrhage in the alveolar wall as well as in the air spaces; × 250.

polymorphonuclear leukocytes in the lung field. No changes in the vascular walls were noted.

In the specimens with lemon seed small amounts of bronchial exudate began to accumulate toward the end of the fourth day. The peribronchial lymph follicles showed only slight proliferation of reticulo-endothelial cells. There was neither edema nor hemorrhage in the alveolar wall, but there was slight evidence of congestion of the bronchial mucosa, as indicated by the dilated blood vessels. There was cellular infiltration in a slight degree by large mononuclear leukocytes. The

most characteristic feature was the comparatively small amount of cellular reaction due to the presence of seeds of citrous fruits.

Grapefruit Seed.—At the end of twenty-four hours the peribronchial lymph follicles showed a slight reticulo-endothelial proliferation. The epithellium of the bronchioles was intact, but the lumen was filled with erythrocytes. The alveolar wall next to the bronchioles also showed hemorrhage.

At the end of forty-eight hours proliferation of reticulo-endothelial cells continued in the lymph follicles. There was a gradual accumulation of bronchial exudate consisting of cast-off epithelium, erythrocytes and a few polymorphonuclear leukocytes. The alveolar wall was definitely swollen and appeared to be irritated, as shown by the proliferation of large mononuclear leukocytes, but there was no desquamation. Proliferation in the endothelial lining of the smaller blood vessels had begun at this stage.

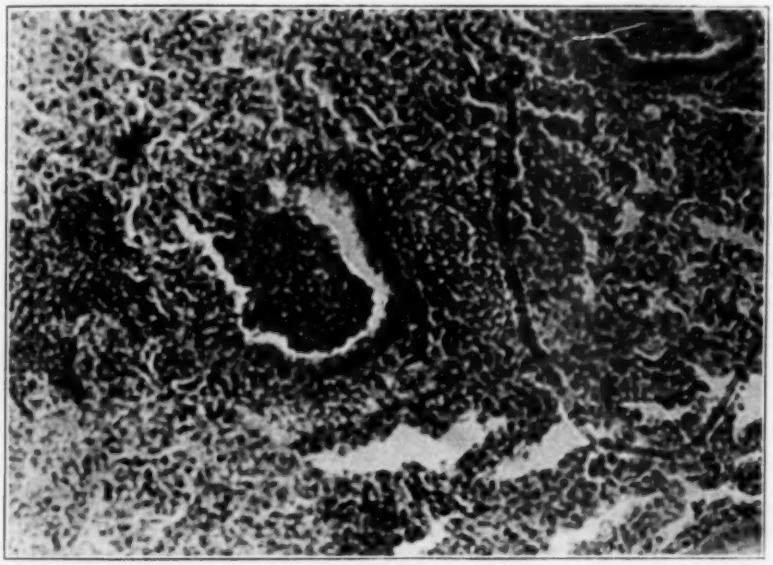

Fig. 9.—A section of rabbit's lung following endoscopic implantation of watermelon seed in the bronchus of the left lower lobe for ninety-six hours. The bronchial epithelial cells are denuded in several places. The exudate within the lumen shows the evidence of an early disintegration. Polymorphonuclear leukocytic infiltration of the bronchial and peribronchial structure is noted. Owing to the accumulation of the diffuse hemorrhagic exudate in the alveoli the pulmonary architecture is almost indistinguishable. The dark areas in the pulmonary field indicate bronchopneumonic patches; × 250.

At the end of seventy-two and ninety-six hours the pulmonary reaction showed a progressive increase. The area of exudation widened. There was a larger amount of bronchial exudate, with the evidence of epithelial denudation. On the fourth day the secondary change was noted in the exudate as shown by the increased activity of the polymorphonuclear leukocytes.

Watermelon Seed.—In the twenty-four hour specimens the most characteristic feature was the comparatively slight reaction produced in the pulmonary fields.

The bronchi and bronchioles were free from exudate, and there was no vascular change. The alveolar walls showed a slight increase in cellular infiltration, largely of the large mononuclear leukocytic type. There were scattered hemorrhages, in both the alveolar walls and the air spaces.

In the forty-eight hour series an advanced reaction was noted. The bronchial epithelium appeared to be detached in many places; its lumen was partially occluded by cast-off epithelium, a few large mononuclear leukocytes and a relatively large number of polymorphonuclear leukocytes and erythrocytes. There was more hemorrhage in the alveolar wall and the alveolar spaces, which at the end of seventy-two hours increased rapidly, filling both large and small bronchioles and the larger pulmonary fields.

In the ninety-six hour series secondary changes due to hemorrhage occurred, leading to bronchopneumonia, as evidenced by the marked increase in polymorphonuclear leukocytes in the exudate and within the mucosa and the submucosa of the bronchi. The picture was that of intense capillary hemorrhage throughout the pulmonary field, followed by patchy bronchopneumonia (fig. 9).

Cantaloupe Seed.—In the twenty-four and forty-eight hour specimens the reaction of the pulmonary tissue was uniformly absent. At the end of four days the bronchial mucosa showed only slight leukocytic infiltration. Even the smallest bronchioles were free from exudate. The alveoli in the immediate neighborhood of the larger bronchi showed slight proliferation of reticulo-endothelial cells. In one of the ninety-six hour specimens there was evidence of a slight endothelial cell proliferation of the smaller blood vessels. Cantaloupe seed was one of the most inert objects studied.

INTERPRETATION OF THE EXPERIMENTS

These foreign bodies brought on a consistent, progressive response in the lower air passages. In the main the results with solids are similar to those reported by Fried and others in their experiments with liquids and fine solids in suspension. The reaction of the lung tissue was both exudative and proliferative. These two processes went on simultaneously. The exudative reaction consisted of a pouring out into the pulmonary alveoli of large, swollen, irritated epithelial-like cells which originated on the septal wall to form the inflammatory alveolar exudate. The proliferative reaction consisted of a multiplication of the cells lining the alveoli, each individual cell becoming swollen and enlarged, and some showing evidence of metamorphosis, their cytoplasm having acquired here and there a vacuolated foamy appearance. The alveolar septum was many times thicker than normal. The reaction increased with each subsequent day until the pulmonary parenchyma lost its normal architecture. The area of exudate thus formed was always limited to the immediate neighborhood of the larger bronchi, and extended outward. The rapidity with which this expansion took place appeared to be in direct proportion to the degree of irritation. Usually at the end of the second and third days the cellular proliferation and alveolar exudate led to areas of diffuse cellular agglomeration occupying several low power microscopic fields. This was not atelectasis in the true sense of

the word. At no time was there collapse of the alveolar walls. On the contrary, the alveoli were visibly distended by rapidly accumulating cellular elements. When examined with the naked eye these seemingly consolidated areas resembled bronchopneumonic patches, but on microscopic examination the lymphocytes and the polymorphonuclear leukocytes were conspicuously absent.

Large mononuclear leukocytes were the principal proliferated cells. There were a number of large multinucleated cells, apparently originating from the septal wall, not by the nuclear division of one particular cell, but by the fusion of many cells, and probably being the precursors of giant cells. Frank capillary hemorrhage in the alveolar wall, and to a certain extent in the alveoli, was noted in lungs containing the bark of eucalyptus, seeds of watermelon, grapefruit and oranges and particularly peanuts.

About the fourth day secondary changes took place in the lungs containing specially irritating substances. This was probably due to the establishment of septic foci in these areas of exudation. The lesion thus produced was always localized pneumonitis and never lobar. The peribronchial lymph follicles showed an early and progressive hyperplasia of the endothelial elements. Vascular change was uniformly that of obliterating arteritis with the foreign body causing marked reaction. The stronger the irritation the earlier the vascular endothelial response appeared, resulting in an infarct. This was most clearly noted with peanuts, bark of the pepper tree and pop-corn. There was no change with inert objects. As far as I am aware, no investigator has called attention to the fact that proliferation of the intima of these vessels leads successively to infarction and focal necrosis of the pulmonary parenchyma in the presence of a foreign body in the bronchus.

The primary reaction in the trachea was also reticulo-endothelial. There was an early mobilization of histiocytes along the basement membrane, and later throughout the tunica propria. This was best seen in the sections treated with Maximow's stain. The epithelial cells were denuded in places and the blood vessels were much dilated. Both mucosa and submucosa were being infiltrated by varying numbers of large mononuclear leukocytes and a few polymorphonuclear leukocytes. The glandular structures showed no alteration. Secondary reaction occurred on the third and fourth days with a purulent exudate in the tributary bronchi and bronchioles. There were an increasing number of polymorphonuclear leukocytes replacing the large mononuclear leukocytes.

APPLIED PHYSIOPATHOLOGY

These experiments are of particular interest to the bronchoscopist. The reaction to various organic foreign bodies in the pulmonary parenchyma from a histologic standpoint is essentially the same, the

difference being one of degree and not of kind. This quantitative difference spells either an early untoward termination or an eventual recovery when the foreign body is successfully removed.

Every foreign body introduced caused purulent exudate of varying amounts in its immediate vicinity. The physiologic purpose is apparent. The coat thus formed not only acted as a mechanical barrier to shut off the injurious influence of the foreign body on the mucosal lining, but was probably chemically antidotal. An enormous outpouring of mucous secretion is one of nature's protective phenomena. When the cough mechanism is impaired and a foreign body coated with thick, purulent exudate tightly corks the already swollen bronchial mucosa a vicious circle is established. This results in a pathologic imbalance which Jackson aptly called a drowned lung.

An interesting observation was made in animals which came to autopsy without foreign bodies. Those which had successfully coughed out the implanted foreign bodies contained large amounts of frothy secretion within their tracheobronchial systems. The mucus thus secreted not only acted as the diluent of the irritating agent, but added a sufficient volume for an easy expulsion by coughing when it was lifted from the bed of the swollen mucosa. I had no means of determining how long the foreign bodies were retained. By gross examination I could not distinguish the lung containing the foreign body from the one without it. This was particularly true of lungs in which irritating foreign bodies had been implanted.

Every one is familiar with clinical cases in which the foreign bodies are successfully removed, but which come to an unhappy ending from two to five days later. At autopsy the lungs always show many areas of localized pneumonitis with a quantity of purulent secretion in the air passages. On microscopic examination of the lungs a number of foci of infection are found. The younger the patient the worse is the prognosis. The rational therapeutic measure, then, is repeated aspiration of the secretion, enabling the establishment of ventilation of the lower air passages, thus facilitating the work of the cough reflex and an early restoration of normal function.

Much discussion has taken place as to the true nature of the irritant in these objects. The work of Heatly and Clausen [38] with peanuts and that of Pinkerton [39] with oil and fat in the lungs show that the offending agent is fatty acid. According to Pinkerton the fatty acid may be originally present in these organic foreign bodies or may be produced as the result of hydrolysis. This explanation appears to be plausible.

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38. Heatly, Clyde A., and Clausen, Samuel W.: Experimental Studies in Peanut Bronchitis, Arch. Otolaryng. **11**:569 (May) 1930.

39. Pinkerton, Henry: The Reaction to Oils and Fats in the Lung, Arch. Path. **5**:380 (March) 1928.

The relation between the area of cellular agglomeration and the development of secondary localized pneumonitis is one of the most interesting features of this study. Cutler and his associates,[40] Scott,[41] Elwyn [42] and others, in their studies on postoperative pulmonary complications, expressed the belief that atelectasis favored the development of bronchopneumonia and, more rarely, pneumonia and abscess of the lung. They considered that this was due to the fixation of septic emboli in the tissue of the affected lung. I believe that replacement of air by the cellular elements in the alveoli brings on precisely similar results.

The occurrence of emphysema next to the consolidated area is probably compensatory. According to Coryllos and Birnbaum [43] the presence of a foreign body in the bronchi stimulated spastic contraction of the bronchial muscle and favored the production of emphysema. I believe, however, that there was an early miniature "check-valve" action of the alveolar ducts next to the consolidated area causing the trapping of the inspired air. This was later followed by the absorption of the trapped air, and it was completely replaced by exudate.

The primary cause of drowned lung is the too rapid and excessive outpouring of mucus and cellular elements in the presence of a decreased or abolished cough reflex. Jackson,[44] from his clinical observation, attributed the repression of the cough reflex to the establishment of tolerance to the foreign body. Larsell and Burget,[45] in their experiment, regarded the lack of bechic response as caused by fatigue.

The rapidity of onset, irritating cough, profound toxemia, marked prostration, intense pallor, cyanosis, anoxemia and myocardial failure in irritating foreign body bronchitis have their counterparts in the changes in the pulmonary tissue, seen in histologic studies as obliterating arteritis, pulmonary infarcts, focal necrosis, capillary hemorrhages and the rapidly spreading area of cellular agglomeration which involves both lungs. This holds true in the uninvaded as well as the invaded lung.

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40. Cutler, E. C., and Hunt, A. M.: Postoperative Pulmonary Complications, Arch. Surg. **1**:114 (July) 1920; Postoperative Pulmonary Complications, Arch. Int. Med. **29**:449 (April) 1922.

41. Scott, W. J. M.: Postoperative Massive Collapse of Lung, Arch. Surg. **10**:73 (Jan.) 1925.

42. Elwyn, H.: Postoperative Pneumonia, J. A. M. A. **79**:2154 (Dec. 23) 1922; **82**:384 (Feb. 2) 1924.

43. Coryllos, Pol N., and Birnbaum, George L.: Obstructive Massive Atelectasis of the Lung, Arch. Surg. **16**:501 (Feb.) 1928.

44. Jackson, Chevalier: Bronchoscopic Observations on Cough Reflex, J. A. M. A. **79**:1399 (Oct. 21) 1922.

45. Larsell, O., and Burget, G. E.: The Effects of Mechanical and Chemical Stimulation of the Tracheo-Bronchial Mucous Membrane, Am. J. Physiol. **70**:71 (Sept.-Nov.) 1924.

While the exact mechanism in each of these steps is not known, the experimental evidence submitted here sheds sufficient light on the path of the bronchoscopist to justify him, in both known and suspected cases of organic foreign bodies in the bronchi, to institute early bronchoscopic treatment.

SUMMARY

1. Experimental study on the reaction of lung tissue to the intratracheal introduction of ten different solid organic foreign bodies by means of peroral endoscopy is reported. The animals were killed at the end of twenty-four, forty-eight, seventy-two and ninety-six hour periods.

2. The gross appearance of the lungs varied considerably according to the objects introduced, the manner of bronchial obstruction and the period of observation which elapsed before the animal was killed. The most intense reaction was noted in lungs containing peanuts, bark of the pepper tree and pop-corn. The seeds of citrous fruits, grapes and watermelon produced a moderate reaction. The least reaction was shown by the bark of the eucalyptus tree and seeds of the cantaloupe.

3. Histologic examination of the lung tissue indicated that the response was progressive, consisting of exudation and proliferation. These two processes went on simultaneously. The exudative reaction consisted of the pouring out of large, swollen, irritated septal cells into the pulmonary alveoli to form an inflammatory alveolar exudate. The proliferative reaction consisted of the multiplication of cells lining the alveoli.

4. The reaction increased with each subsequent day until the pulmonary parenchyma lost its normal architecture. The area of exudate formed was always limited to the immediate neighborhood of the larger bronchi and extended outward. The rapidity with which this expansion took place appeared to be in direct proportion to the degree of irritation.

5. Secondary change in the lungs was always localized pneumonitis, never lobar. This occurred on the third or fourth day in lungs containing the most irritating foreign bodies.

6. The large mononuclear leukocytes were the principal proliferating cells. These showed a tendency to form large multinucleated cells, probably precursors of the giant cells. They were shown best in lungs containing grape seed.

7. Vascular change was uniformly that of obliterating arteritis with a foreign body causing a marked reaction. This proliferative change in the endothelial lining of the blood vessels brought on, successively, infarction and focal necrosis of the pulmonary parenchyma.

8. Frank capillary hemorrhage in the alveolar wall, and to some extent hemorrhage in the alveoli, was noted in lungs containing pop-corn,

the bark of the eucalyptus tree, the seeds of the watermelon, grapefruit and orange and, particularly, peanuts.

9. Similar changes were noted in the opposite lungs, which contained no foreign bodies.

10. The primary cause of drowned lung is the too rapid and excessive outpouring of mucus and exudate in the presence of a decreased or abolished cough reflex.

11. The rapidity of onset and subsequent clinical symptoms due to the presence of organic foreign bodies in the bronchi have their well defined histologic counterparts during each stage of their development.

News and Comment

AMERICAN BOARD OF OTOLARYNGOLOGY

An examination was held in Chicago, on Sept. 8, 1934, during the meeting of the American Academy of Ophthalmology and Oto-Laryngology. Sixty-two candidates were examined, of which number thirteen were conditioned or failed.

The board will hold an examination in San Antonio, Texas, on November 13, during the meeting of the Southern Medical Association. During 1935, examinations will be held in New York, in the spring, at the time of the meeting of the American Medical Association, and in Cincinnati, in the fall, just prior to the meeting of the American Academy of Ophthalmology and Oto-Laryngology. Applications for certificate should be addressed to the Secretary, Dr. W. P. Wherry, 1500 Medical Arts Building, Omaha.

Clinical Notes

THE ACOUSTIMETER

A Device of Tuning Forks with a Graphic System for Charting Acuity of Hearing

AARON ROTH, M.D., BROOKLYN

It has been my objective to accomplish the following: (1) to devise a system of charting acuity of hearing by means of tuning forks; (2) to construct the mechanical means that will eliminate the examiner's ear in the test; (3) to make the device simple and free of all electrical and intricate elements, and to avoid bone or tissue conduction of sound to the examined ear, thus obviating erroneous records from this source; (4) to construct the device so that it may be produced inexpensively.

MECHANISM

The acoustimeter is an arrangement of tuning forks in series, mounted on a revolving base. A turn brings each fork into position to be struck by a hammer centrally mounted to serve all the forks. The hammer is actually a pendulum weighted on the free end. A stop-watch is connected with the pivotal end of the pendulum. When the hammer is released the watch starts automatically. The hammer being released from a constant level, there is a constant force of strike on the forks; as a consequence the forks have a constant intensity at the maximum and a constant period of decline from the maximum to the point of lost audibility for the normal ear.

An ear holder is a fixed part of the equipment and serves to keep the examined ear at a constant distance from the source of sound. A sound interrupter is connected with the ear holder and is operated by means of a handle which the examiner moves to and fro when the region of fading audibility is reached; the use of this interrupter obviates nerve fatigue and aids the patient in defining the last point of audibility.

Thus all the necessary elements of mechanical constancy have been combined, making this device a sound-producing medium of constant intensities. It is a mechanism of tuning forks which eliminates the need for the examiner's ear in testing acuity of hearing. In practice the patient holds his ear in position after the hammer has been released; the examiner simply notes the number of seconds that have elapsed when the patient announces lost audibility, and he then refers to a table of values provided with the instrument. The table gives the values in decibels and in percentage of acuity; the percentage of acuity is marked on the chart in the column for the fork used. The marks in all the columns are connected by a line representing the record for acuity.

The conception of the acoustimeter embraces also a rational charting system with results of tests for acuity that will be similarly interpretable universally. This calls for general agreement on the question—"What is the normal range (scale) of hearing from perception of the strongest intensity to that of the weakest intensity for each pitch?" For it is clear that if one is to measure impairment one must have a universally accepted scale as a standard of comparison. It is clear, too, that this scale, just like any measuring scale, must have two fixed

limits. In a consideration of the normal scale of hearing the lower limit is known to the point of lost audibility in the normal ear. What, then, is the upper limit for the normal ear? That limit is obviously not definitely determinable, but for measuring purposes it must be set arbitrarily. The upper limit as fixed by the telephone industries is based on reasonable experimentation. Fletcher and others have defined the upper limit as the region at which an additional increase of intensity is appreciated as a sensation of tickling and then of pain. While this level of transition is not the same for normal ears, Fletcher makes use of the average result after testing a large group of persons. Thus this line represents as

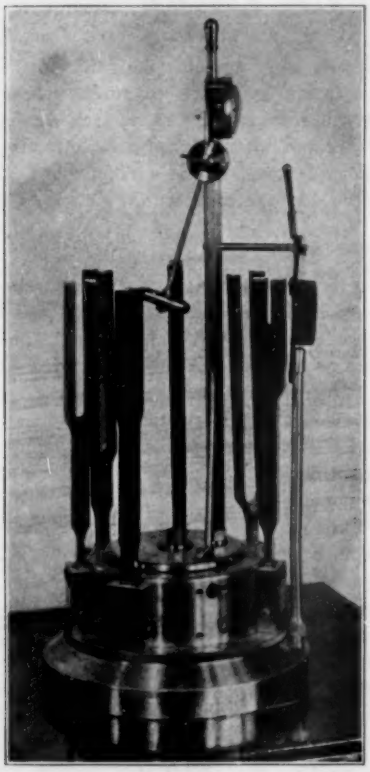

Fig. 1.—The acoustimeter, showing the arrangement of tuning forks and the centrally mounted hammer.

close an approximation as is theoretically conceivable in forming the upper level of the measuring scale. In view of the fact that the acoustic industries throughout the world have gradually accepted this upper boundary as a convenient and useful standard for computations, I am also using it as the upper limit in the calculation of values for acuity.

On the acoustimeter all the forks have been calibrated, and the rate of decline in perceptible degrees of intensity of sound per second (decibels per second) is known for each fork. The rate of decline per second is known in the nomenclature of acoustics as the fork constant.

When the constant factors are known, the acuity in any case of impairment is the ratio between two figures; the table of reference is based on this ratio.

1. The denominator is the number of seconds that would elapse if the given fork were made to decline from the arbitrary upper threshold (if it were struck with enough force).

2. The numerator is the time in which the sound is audible to the patient, that is, the number of seconds between the upper threshold and the point of lost audibility.

It is to be noted that the upper threshold of intensity is not produced for practical purposes, but it is taken into account in the calculations. I shall show by an example how the calculations are made. (The figures here tabulated

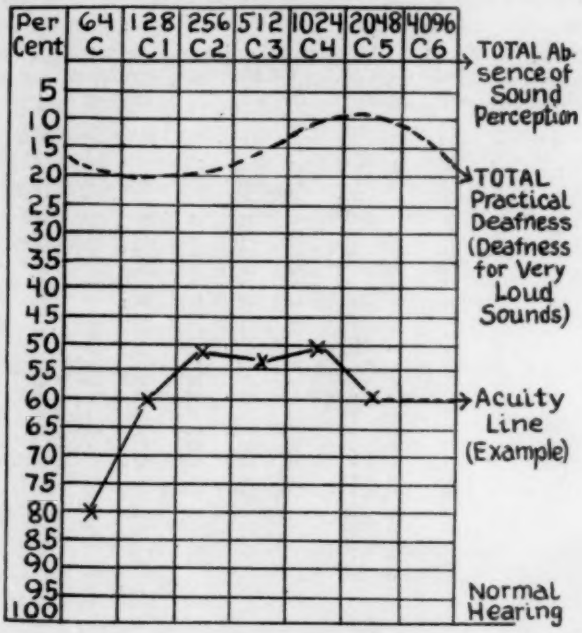

Fig. 2.—Chart for hearing acuity.

and explained are based on the tuning fork periods of my experimental model. These periods are much too long for practical clinical use. In my last model the periods have been reduced from one half to one third the time by modifying the forks during the process of manufacture, in accordance with the suggestion of Dr. Vern O. Knudsen, professor of physics, University of California. The result is that a very short time is required for the clinical examination of a patient. [The tabulations, of course, are made from the respective forks.] The tabulations shown in this article were made by Dr. Knudsen in connection with my experimental model.)

In the last model a removable fork unit has been added to the C256 for timing bone conduction and recording the Rinne test in definite time values.

On the experimental model of my acoustimeter the C512 fork has three constant factors. 1. The upper threshold for this pitch is 128 decibels of intensity. 2. The

fork constant is a decrease of 0.52 decibel per second. 3. The normal time from the strike of the hammer to lost audibility is 172 seconds (in a very quiet room).

If the patient ceases to hear at the end of 60 seconds, he has lost 112 seconds from the normal time of audibility of the fork, which normally should have been heard for 172 seconds (172 minus 60 equals 112). But one must figure the loss from the total range, that is, from the threshold. It is known that at the threshold the maximum intensity is 128 decibels. Since the intensity of sound of this fork decreases 0.52 decibel per second, the number of seconds required for the fork to decline from the upper threshold to zero would be 128 divided by 0.52, or 246.

*Value for Loss of Hearing and Percentage of Acuity**

	110		150		200		180			130		9			
	C 64		C 128		C 256		C 512			C 1,024		C 2,048		C 4,096	
δ	0.41 Db.†		0.38 Db.		0.33 Db.		0.52 Db.		δ	0.90 Db.		1.90 Db.		5.25 Db.	
to	182 (Sec.)		194 (Sec.)		220 (Sec.)		172 (Sec.)			118 (Sec.)		53 (Sec.)		15 (Sec.)	
Time, Seconds	Loss, Db.	Hearing, per Cent	Loss, Db.	Hearing, per Cent	Loss, Db.	Hearing, per Cent	Loss, Db.	Hearing, per Cent	Time, Seconds	Loss, Db.	Hearing, per Cent	Loss, Db.	Hearing, per Cent	Loss, Db.	Hearing, per Cent
5	52	17	72	21	71	37	87	32	1	106	20	90	23	73	37
10	50	21	70	23	69	39	84	34	3	104	21	95	26	63	46
15	48	24	68	25	68	40	82	36	5	102	23	91	29	52	55
20	46	27	66	27	66	42	79	38	7	100	24	87	32	42	64
30	42	33	62	32	63	45	74	42	9	98	26	84	35	31	73
40	38	40	58	36	59	48	69	46	11	96	27	80	38	21	82
50	34	46	55	40	56	51	63	51	13	94	29	76	41	10	91
60	29	53	51	44	53	53	58	55	15	92	30	72	44	0	100
70	25	60	47	48	50	56	53	59	20	88	33	63	51		
80	21	67	43	52	46	59	48	63	25	84	36	53	59		
90	17	73	40	56	43	62	43	67	30	79	40	44	66		
100	13	80	36	60	40	65	37	71	35	75	43	34	73		
110	9	86	32	65	36	68	32	75	40	70	47	25	80		
120	5	92	28	69	33	71	27	79	45	66	60	15	88		
130	1	98	24	73	30	74	22	83	50	61	54	6	95		
140	..	..	21	77	26	77	17	87	60	52	61				
150	..	..	17	86	20	82	6	95	70	43	68				
160	..	..	9	90	17	85	1	99	80	34	74				
170	..	..	5	94	13	88	..	..	90	25	81				
180	..	..	2	98	10	91	..	..	100	16	88				
190	..	..	..	..	7	94	..	..	110	7	95				
200	..	..	..	..	3	97	..	..	118	0	100				
210	..	..	..	..	0	100									
220															

* The values in this table are calculated for a very quiet room; δ indicates the rate of decline of intensity per second (fork constant), and to the normal period of audibility.
† Decibels.

The patient lost the last 112 seconds of the fork's sound; he also lost the last 112 seconds as calculated on the total scale; he lost $\frac{112}{246}$ of the range of hearing, i. e., 45 per cent. He retained 55 per cent. In decibels he lost 112×0.52, that is, 58.

In considering the lowest readings on the table one must not lose sight of the fact that the readings represent the percentages of acuity based on the total scale; the values are not based on the ratio between impaired acuity and the acuity of practical normal hearing. Hence an acuity of 20 per cent may show the patient to be quite deaf to loud conversation, yet not deaf to extra loud experimentally produced sounds.

It is evident that a tabulation of values for acuity is easily made for any room, that is, a table of values corresponding to the normal time in seconds in which a

given tuning fork is heard in a moderately noisy or in a sound-proof room. No matter what method is used, whether electrical or tuning fork tests, acuity will vary with the room unless it is very quiet. In a moderately noisy room it is important to determine the normal values for that room and then to make a permanent reference table of values. If this is done (and it should be done if a very quiet room is not available) the results in percentages will be similarly interpretable universally. The table provided with the instrument should be for a very quiet room with a minimum of vibrations. It must be remembered that stopping the ears will not produce the same effect as a quiet room because the noises and vibratory effects of street sounds are conducted to the centers of perception through the bones and especially through the spinal column. The effect of a noisy room on records of acuity will be relatively unimportant in the tests if one takes into account the normal values for that room. This observation applies to electrical audiometers as well as to tuning forks.

Prof. Vern O. Knudsen tested the constancy of this device in his physical science laboratory at the University of California and made the valuable suggestion as to the use of a separate reference table of values for convenient and ready use in clinical practice; this grealty simplified the percentage chart and the interpretation of impairment values at a glance. Professor Knudsen corresponded with me at length regarding the necessity of modifying the forks to shorten their period of decline and gave me many points on acoustics which gave me a wider view of my own invention.

570 Eastern Parkway.

INSTRUMENTS FOR OPERATION ON THE PETROUS PYRAMID

MERVIN C. MYERSON, M.D.; HERMAN RUBIN, M.D., AND JOSEPH G. GILBERT, M.D., NEW YORK

This set of instruments is specially designed for uncapping the petrous apex, and for exenterating such part of its cellular structure as may be indicated in a given case. There are three gouges and four types of curets. The handles are especially long, and are so angulated as to enable the operator to reach readily

Fig. 1.—Angulated gouge for uncapping the apex cell area.

the anterior surface of the petrous pyramid in the apex area or any other part after the temporosphenoidal lobe of the brain has been elevated.

The gouges are 2.5, 3.5 and 5 mm. wide, respectively.

The curets are upward cutting, downward cutting and forward and backward cutting. The forward cutting curet for the right side becomes a backward cutting

From the Department of Otolaryngology, Kings County Hospital.

curet for the left, while the backward cutting curet for the right side becomes a forward cutting curet for the left. With the curets we were able completely to uncap the anterior surface of the petrous pyramid in a recent case. We found a fistulous tract leading into the mastoid area from a point just above the superior semicircular canal. Despite enlargement of the fistula and its tract there was retention, so the next day it was necessary to uncap the roof of the petrous bone along the involved tract of cells, down into the tip of the apex. No difficulty was experienced in accomplishing this.

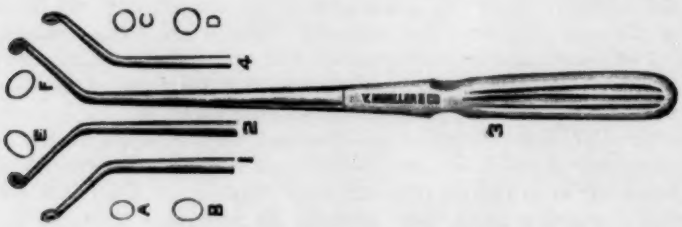

Fig. 2.—Curets for use in different directions.

Fig. 3.—Brain elevator and suction tube for keeping the area of operation clean and aspirating the apex.

In performing the operation the gouges are placed on the distal or internal lip of the internal auditory meatus; firm pressure with the hand or a light stroke with a mallet will uncap the average tip cell. This opening is enlarged by means of curets. A curved suction tube is used for aspirating the area. A probe with special markings to help gage the distance from the eminence above the superior semicircular canal to the petrous tip is also used. Two 10 or 12 mm. brain retractors are included in the set.

136 East Sixty-Fourth Street.

Progress in Otolaryngology

A Summary of the Bibliographic Material Available in the Field of Otolaryngology

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PLASTIC SURGERY

J. EASTMAN SHEEHAN, M.D.
NEW YORK

Possibly the most suggestive contribution to the recent literature on plastic surgery is that in which Staige Davis,[1] in contending that a special branch of surgery has come into existence, outlines the form of organization he considers should be adopted by every great teaching hospital with a view to making the specialty of the highest service to the greatest number. If the teaching bodies, and especially the persons who direct them, can be induced to regard this as the reasoned expression of a sound view based on the experience of Davis, under encouragement received at Johns Hopkins Hospital, much of the hesitation that has been manifest hitherto may disappear. It is not an overstatement that some of the most competent directors of hospitals hesitate to create, or even to recognize, a department devoted to this order of reparative surgery, on the plea that while the capacity of an individual may be conceded, it is problematic whether he could be replaced. Nevertheless, in one hospital after another such departments have been brought into existence, largely by official concession to individual initiative, so that what Davis advocates is not something to be evolved as a doubtful experiment but something that in most of its features already exists and awaits only the interest that would tend to perfect it.

Surgeons are entitled to draw the inference that there is here a definite opening for a career, but they would do well, if impressed by that idea, to give heed to the admonitions contained in Davis' article. It is not for every general surgeon to assume that the work is "plain sailing," and it is equally unsafe to believe that the technic can be picked up casually and without the most thorough preparation as a surgeon. Transplanted tissues offer many surprises to the general surgeon, and, on the other hand, those who believe that the correction of familiar disfigurements is all that is required will do well to abandon that view and to realize that the demands made are of infinite variety and are certain, on occasion, to require the utmost of the operator's combined knowledge and skill. Unless all this is recognized, Davis

1. Davis, J. S.: The Division of Plastic Surgery, South. Surgeon **2**:136 (June) 1933.

would be premature in prescribing the details of an organization, since it could not be manned. But as such departments have been organized and function year after year, all that remains is for aspirants to a share in the work to equip themselves for its severest requirements.

To those who have the idea that the use of skin grafts calls for little or no discrimination, a discussion by Kazanjian [2] offers material for reflection. He shows that care must be taken, with due regard for texture, coloration and vitality, if the operator is to be spared the disappointment of having what was designed as a correction eventuate in a new blemish. Kazanjian gives a useful analysis of the many forms disfigurement may assume in connection with that extremely vulnerable organ, the outer nose. While these disfigurements may be reduced to two essentials, displacement of framework and loss of tissues, the literature reveals how extensive an effort is made to devise methods that will leave a presentable appearance, including the elimination of a scar. This is true not only of skin grafts, but of repair and replacement. Watkins,[3] for example, deals with fracture of the nasal bones, emphasizing early mobilization of the fragments and the judicious retention of the parts in the correct positions until there is no longer danger of deformity being produced; he elaborates the possibilities of benefit from employing an internal splint in such cases, either as a support or for holding a Thiersch graft in place. McIndoe [4] gives the results of experiments with various forms of cartilage, according to the degree of depression of the bridge which has to be overcome. He has had occasion to note the tendency of bone to absorb when used as a support for the nose. Although this has been demonstrated many times, as has the fact that cartilage lives and does not disintegrate when placed among living tissues, the fact that bone lives when applied to bone continues to tempt those who have not kept pace with the literature. McIndoe's paper carries valuable suggestions as to the advisability of retaining the perichondrium with implants of cartilage. Generally, the conclusion is negative, as the influence is to alter the line, a serious defect on the dorsum of the nose; but there are exceptions, as at the hinge of the long and the short leg of the implant and at the junction with the crest of the maxillae.

Much the same comment may be made on the contribution by Blair and his associates,[5] in which refinements of methods in effecting repairs

2. Kazanjian, V. H.: Nasal Deformities and Their Repair, Laryngoscope **43**:955 (Dec.) 1933.

3. Watkins, A. B. K.: Notes on Nasal Plastic Surgery, J. Laryng. & Otol. **48**:809 (Dec.) 1933.

4. McIndoe, A. H.: Restoration of Depressed Nose by Grafting Cartilage, Proc. Roy. Soc. Med. **27**:127 (July) 1934.

5. Blair, V. P.; Brown, J. B., and Hamm, W. G.: Types of Reconstructive Surgery of the Orbital Region, South. Surgeon **1**:293 (Jan.) 1933.

in the orbital region are given. There is no new principle to be evoked in the correction of ptosis, epicanthus, etc. This account serves as a useful reminder of what may be gained by careful attention to planning and execution, and illustrates again, in the example of covering eyelids from which a scar has been removed, the need for choosing the best graft for covering the defect as determined by conditions in the immediate instance. One interesting experiment noted is the use of gold radon seeds in treating hemangioma of the lids. That gold has an inhibiting influence on noxious rays is one of the assumptions concerning which therapeutists are at the moment most hopeful in their continuous effort to avoid baleful results while enlarging the field to which rays can be beneficially applied.

Goodyear [6] reports an operation for protruding ears, noting the danger of chondritis when the auricular cartilage is incised and suggesting expedients for avoidance of that course when possible. Esser [7] has made an elaborate study of the artery pedicle graft, the use of which for the regeneration of atonic areas was first demonstrated by Monks. Esser's study concerns the tissues and vessels surrounding the artery, the effect of transfer on the return blood flow, the nerve supply and the influence of the skin if retained.

Daggett and Bateman [8] report seventy-one cases of grafting of the mastoid cavity through the external acoustic meatus. The meatus is enlarged under gas anesthesia, and the dressings are changed from the seventh to the fourteenth day; on the fourteenth day, under N-methyl-cyclo-hexenyl-methyl barbituric acid the graft is inserted and is held by wax. The wax is removed on the twenty-eighth day, the graft is powdered, and inspection is continued at intervals. New methods are also introduced by Babcock [9] in his description of procedures for the enlargement of the lumen of the trachea, which include V-shaped excisions of cicatricial tissues, the use of one or more pedicle grafts and the removal or substitution of cartilage as may be needed.

I [10] have developed a method for the correction of unilateral facial paralysis by bringing reanimation to the paralyzed muscles by close contact with strips of the temporal muscle, carried to the corner of the mouth, across the eyelids and to the frontalis muscle. The strips can

6. Goodyear, H.: Plastic Operation for Protruding Ears, Arch. Otolaryng. **18**:527 (Oct.) 1933.

7. Esser, J. F. S.: Preservation of Innervation and Circulation, Supply in Plastic Restoration of Upper Lip, Ann. Surg. **99**:101 (Jan.) 1934.

8. Daggett, W. I., and Bateman, G. H.: Secondary Thiersch Grafting of the Radical Mastoid Cavity Through the Meatus, J. Laryng. & Otol. **49**:169 (March) 1934.

9. Babcock, W. W.: Plastic Closure of Laryngostomic Fistulas, Arch. Otolaryng. **19**:585 (May) 1934.

10. Sheehan, J. E.: Plastic Surgery, M. Rec. **139**:647 (June 20) 1934.

be taken without impairing the function of the temporal muscle in relation to the lower jaw. The instant disappearance of lagophthalmos is a feature of the operation.

Marion Douglass [11] justifies a preference for the use of skin flaps in reconstruction of the vagina, as opposed to other methods.

It is highly interesting to note that alongside the intensive research in the endocrine field, which is perhaps the most significant of present-day developments, there is also going on some serious and competent experimentation as to the effect of introducing living grafts. Stone and his associates [12] present an uncompleted report of such experiments. Their plan includes investigation of the possibility of establishing a method of heterografts. They have succeeded in transplanting endocrine glands that are living and apparently functioning after a considerable period of time. Of this, they present both experimental and clinical evidence, and their success has been sufficient to encourage them to continue in the hope of establishing a uniformly successful technical method. They stress the need of (*a*) a properly chosen site into which the graft is to be placed; (*b*) concern for the physical form of the graft, and (*c*) adaptation of the graft to the specific chemistry of the host.

In the field of restatement, there are several offerings of note. Harbin and Liber [13] review the various types of bone grafts, moved thereto by a desire to discover an underlying principle by which conflicting theories and variations in practical results can be reconciled. Starting from the fact that regeneration of bone depends on the blood supply, they investigate the differing speed by which different nutrient vessels conduce to that regeneration. Once the typical behavior is realized, choice and expectation can be adapted to the given situation. Freda Parsons [14] reviews the factors inhibiting the production of normal speech in cases of cleft palate. Luongo [15] furnishes a comprehensive review of the literature on dermoid cyst of the nasal dorsum. Staige Davis [16] has compiled a bibliography on sutures, with a plea for the use of the vertical mattress suture.

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11. Douglass, Marion D.: Reconstruction of the Vagina, Surg., Gynec. & Obst. **58**:982 (June) 1934.

12. Stone, H. B.; Owings, J. C., and Gey, G. O.: Living Grafts of Endocrine Glands, Am. J. Surg. **24**:386 (May) 1934.

13. Harbin, M., and Liber, K. C.: The Behavior of Transplanted Bone a Clinical Consideration, Surg., Gynec. & Obst. **59**:149 (Aug.) 1934.

14. Parsons, Freda: Speech Training for Cleft Palate Patients, Proc. Roy. Soc. Med. **27**:1301 (July) 1934.

15. Luongo, R. A.: Dermoid Cyst of the Nasal Dorsum, Arch. Otolaryng. **17**: 755 (June) 1933.

16. Davis, J. S.: The On-End or Vertical Mattress Suture, Ann. Surg. **98**:941 (Nov.) 1933.

A useful study of the formation and subsequent importance of cicatricial scar is furnished by Beekman and O'Connell.[17] An understanding of contractile scar and of its bearing on function as well as on esthetic values is essential in reparative surgery, a high percentage of surgical intervention being determined by its presence. Camrady [18] also deals effectively with this subject. At the other end of the scale is an article by Davis and Kitlowski [19] describing experiments to determine at what period sensation returns in the process of restoration by skin grafting. The time taken is longer than might be thought from the appearance of the graft, and even the beginnings of sensation differ with the type of graft. It is a maxim of experience that time is the solvent of most of the symptoms of delay, and with this knowledge of the rate at which improvement may be looked for, much needless apprehension, based on doubt, may be dispelled. Mention was made in my review last year of experiments designed to determine a biochemical standard that might serve as an advance indication of the viability of full thickness skin grafts. This has since been elaborated in the course of an address. Briefly, a standard of oxygen content of the skin can be fixed, tests can be made, and, if the content is too low, means can be taken to bring it up to the standard before operation. The object is, of course, assurance of a "take," now almost absolute except where there are unusual chemical conditions.

There have been numerous discussions of individual surgical problems. Schrock and Johnson,[20] for example, deal with contracture of the palm. Sloughing was experienced when an area greater than the palmar surface was covered by full thickness graft. I [10] have not had that experience in similar cases. Pierce and O'Connor [21] have devised one more operation for reconstruction of the lip, the sixty-sixth. Hardy [22] believes the operation for simulating the cupid's bow can be improved by a dental device bringing the vermilion border more into view through protrusion of the lip. Albert D. Davis [23] cites an instance

17. Beekman, F., and O'Connell, R. J., Jr.: The Healing of Surface Wounds, Ann. Surg. **98**:394 (Sept.) 1933.

18. Camrady, J. E.: Treatment of Superficial Granulating Wounds, Am. J. Surg. **25**:288 (Aug.) 1934.

19. Davis, J. S., and Kitlowski, E. A.: Regeneration of Nerves in Skin Grafts and Skin Flaps, Am. J. Surg. **24**:501 (May) 1934.

20. Schrock, R. D., and Johnson, H. F.: The Free Full-Thickness Skin Transplants, Nebraska M. J. **19**:91 (March) 1934.

21. Pierce, G. W., and O'Connor, G. B.: A New Method of Reconstruction of the Lip, Arch. Surg. **28**:317 (Feb.) 1934.

22. Hardy, E.: The Dental Aspect of Cleft Palate, Proc. Roy. Soc. Med. **27**: 1303 (July) 1934.

23. Davis, A. D.: Rôle of Plastic Surgery in Relation to Orthodontia, Internat. J. Orthodontia **19**:1214 (Dec.) 1933; Palatoplasty, Using Extra-Oral Tissues, Ann. Surg. **99**:94 (Jan.) 1934.

in which a tubed pedicle skin graft, taken from the abdomen, was utilized to close an intra-oral cavity, instead of an obturator, the use of which he censures. Condemning removal of the premaxillae, he makes a strong plea for cooperation between the orthodontist and the plastic surgeon in all that concerns abnormality of the oral cavity.

At every turn, in reparative surgery, there is need of some form of prosthesis. The subject has had more attention in practice than in the literature. Kazanjian,[24] who has never underestimated its importance, has contributed out of his experience what may well prove valuable to others. He, more than most, has given consideration to the utility of prosthetic appliances to restore the esthetic balance in cases in which the ravages of disease have resulted in losses it might be difficult to replace by other means.

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24. Kazanjian, V. H.: Dental Prosthesis in Relation to Facial Reparative Surgery, Surg., Gynec. & Obst. **59**:70 (July) 1934.

Abstracts from Current Literature

Ear

INTERNAL AUDITORY ARTERY IN RELATION TO ARTERIOSCLEROSIS. E. BOZZI, Arch. ital. di otol. **46**:100 (Feb.) 1934.

Bozzi reviews the literature on the relation of the internal auditory artery to arteriosclerosis and cites the importance of arteriosclerosis as a determining factor in presbycusis. He made a systematic study of the wall of the internal auditory artery, particularly as regards sclerosis, and a histologic examination of this artery in its free portion in 100 patients, almost all of whom were 50 or more years of age. The results obtained were compared with the condition of the rest of the arterial system. On the basis of many observations on the relations of arteriosclerotic conditions in different localizations and of the finding of intimal sclerosis or true arteriosclerosis in the auditory artery in 29.7 per cent of the patients examined who were more than 50 years old, the author states that the behavior of the auditory artery is like that of the other organic arteries in the presence of arteriosclerosis. He considers the increased rigidity of the peripheral vessels an associated factor which is always preeminent in presbycusis. He regards the local anemia due to the prolonged spasms of the blood vessels mainly as the mechanism of the principal action on the neuro-epithelium of the organ of sense. Regarding the conditions of the auditory artery and the cerebral arteries, he states that the changes in the two vascular territories need not correspond in point of time, nor should the degree of severity of the disease be expressed in absolute terms.

EDITOR'S ABSTRACT.

NYSTAGMUS ALTERNANS: THREE CLINICAL OBSERVATIONS. G. CANTELE and K. GRAHE, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **137**:174 (Dec. 11) 1933.

Cantele and Grahe observed three cases of the rare nystagmus alternans. In the first case, changed nystagmus occurred only on cold irrigation of both ears and warm irrigation of the left. In the other two cases, changed nystagmus resulted merely from prolonged observation. The authors conclude from their observations that every nystagmus has a counteractivity which, under normal conditions, is inhibited by a checking influence. In the absence of this checking activity as a result of central toxic or infectious factors prolonged alternating nystagmus may develop.

EDITOR'S ABSTRACT.

IS DISTINCTION IN ACUTE MESOTYMPANAL, EPITYMPANAL AND RETROTYMPANAL OTITIS MEDIA LEGITIMATE? W. VAHLDIECK, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **137**:187 (Dec. 11) 1933.

The structure of the ear makes it impossible to draw a distinct line between inflammations of the parts. In all instances of otitis media, whether the condition is called by one name or another, the term is relative, since in inflammation which is primarily mesotympanal the other portions are involved to a lesser degree. Vahldieck discusses the 561 cases of acute otitis observed within the last six years at the Marburg clinic. Of these, 326 were primarily mesotympanal; 259 remained mesotympanal, 28 became epitympanal and 39 became retrotympanal. Of 148 epitympanal cases, 113 remained epitympanal and 35 became retrotympanal. There were 87 cases involving the retrotympanum. Only 29 per cent of the patients having epitympanal inflammation were operated on. Because of the more complicated factors of prognosis and treatment, the author believes that all cases of epitympanal or retrotympanal otitis should be recognized and turned over to a specialist.

EDITOR'S ABSTRACT.

SECONDARY EFFECTS OF RAPID FALLING: III. ANATOMOPATHOLOGIC OBSERVATIONS AND THEIR RELATION TO FUNCTIONAL RESULT. G. CANTELE and K. GRAHE, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **137**:253 (Dec. 20) 1933.

Cantele and Grahe carried out tests by allowing guinea-pigs to fall a distance of from 7 to 15 meters. In one group of experiments the head was up, in another the head was down and in a third the abdomen was down. In all instances in which the animals survived long enough for testing there were definite changes in equilibrium. An anatomic study of the animals immediately after the blow showed, besides injuries to the abdominal and pulmonary cavities, tearing of the ear and hemorrhage in the cochlea. There was also definite congestion of the entire external ear. In the brain there was much basal meningeal hemorrhage, and in the brain substance and brain stem there were microscopic hemorrhages. Venous congestion was present throughout. This generalized circulatory congestion is a sign of shock. The authors conclude that in injuries of such severity as to endanger life, disturbance of the equilibratory mechanism is relatively unimportant.

EDITOR'S ABSTRACT.

THE AUDITORY OSSICLES IN THE ROENTGENOGRAM. F. H. TER HEEGE, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **137**:367 (Dec. 20) 1933.

Ter Heege describes a method of visualizing the auditory ossicles in the middle of a lead matrix. He carefully describes an instrument for obtaining the exact direction and distance for best showing the ossicles.

EDITOR'S ABSTRACT.

ACUTE PURULENT OTITIS MEDIA WITH DIPHTHERIA. E. BERGH, Monatschr. f. Ohrenh. **68**:1 (Jan.) 1934.

In this report Bergh reviews the cases of otitis media occurring in 2,425 patients suffering from diphtheria observed from 1921 to 1930. Acute disease of the middle ear occurred in 121. It was one-sided in 61.2 per cent. There was considerable variation in the frequency of otitis as a complication of diphtheria both from year to year and in different seasons. The third quarter of the year showed the lowest incidence of otitis. The largest number of cases of diphtheritic otitis occurred between the first and sixth years of life, although the largest number of patients having diphtheria were aged from 6 to 8. The frequent occurrence of otitis in diphtheria falls from the first to the ninth year (with the exception of the eighth), and after this year the incidence is slight. Without doubt nasal diphtheria is more dangerous from the standpoint of complication with otitis than diphtheria of the throat. About half the cases of otitis occurred after the twenty-first day of the diphtheria. The appearance of otitis has no influence on the mortality from diphtheria, but there was a parallelism between the mortality rate and the frequency of complications in the middle ear. About two fifths of the patients with diphtheritic otitis have an afebrile course. The prognosis of this type of otitis is good in regard to life and to mastoid complications. Attempts to prevent complications in the middle ear as a result of diphtheria should be based on careful hygiene of the upper respiratory tract and especially of the nose.

EDITOR'S ABSTRACT.

PROTEIN THERAPY OF INFECTIOUS ACOUSTIC NEURITIS. P. ZÁVIŠKA, Monatschr. f. Ohrenh. **68**:25 (Jan.) 1934.

Záviška treated twenty-six patients with impaired hearing due to neuritis of infectious origin with injections of various foreign proteins. There was marked improvement in hearing in nearly all instances. Leukocytosis was found to follow the injections of protein in a few hours. However, the author feels that the favorable results obtained were due not only to the leukocytosis but to some substance produced which weakened the action of the toxins or other bacterial poisons.

EDITOR'S ABSTRACT.

TESTING ONE-SIDED DEAFNESS. E. CHARSCHAK, Monatschr. f. Ohrenh. **68**:34 (Jan.) 1934.

Hearing tests with the Bárány noise apparatus have some advantages but have the great disadvantage of considerably decreasing the acuity of hearing in the opposite ear. Charschak believes that this is due to the conduction of the sound waves produced by the apparatus through the air, through the bone and by reflex action through the cerebral centers of hearing. In an attempt to overcome this difficulty, the author attached the noise apparatus to a rubber tube 1 meter long through which the noise was transmitted to one ear; thus bone conduction was practically eliminated. The noise apparatus was also packed in thick layers of cloth to reduce the air conduction. After these steps were taken and the apparatus was tested on the involved ears of six patients with known organic one-sided deafness, no appreciable decrease in hearing occurred on the contralateral side. When the test was applied to persons with normal hearing, however, a definite decrease in hearing occurred on the opposite side. The author believes that the cause lies in a reflex action along the acoustic nerve to the nucleus of the trigeminal nerve and the muscles of the opposite ear similar to that affecting the normal reaction of the pupil to light. If, then, when the affected ear is tested by the modified noise apparatus hearing is only slightly decreased on the opposite side, deafness is established. Simulated deafness can be easily exposed by this means since the patient cannot well guess what the object of the test is.

EDITOR'S ABSTRACT.

HEREDITARY DEAF-MUTISM. K. CSÖRSZ and L. TOKAY, Monatschr. f. Ohrenh. **68**:42 (Jan.) 1934.

By studying the tree of a family of deaf-mutes, Csörsz and Tokay found that the marriage of two apparently healthy members of hereditarily affected families resulted in both normal and deaf-mute children. Pure deaf-mutism in the children resulted from the marriage of two deaf-mutes. More difficult to explain by hereditary laws was the freedom from deaf-mutism of the children of another intermarriage. The authors propose several possibilities as working hypotheses to explain this inheritance: that the hereditary diseases in all probability have developed by mutation and in various places during the course of human history; that the shifting of the genes that have undergone mutation in a pathologic direction varies in degree; that in a heterozygous person both branches of the pair of genes strive to be independent and the result of this rivalry is the development of intermediary forms or the appearance of only one branch (dominance, recessiveness).

EDITOR'S ABSTRACT.

CHANGES IN THE NERVE APPARATUS OF INFLAMED TYMPANIC MEMBRANES. L. RIEGELE, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:139 (Feb. 10) 1934.

Riegele studied the nerves of the tympanic membrane in preparations stained by the Bielschowsky method. He observed that in the part of the nervous pericapillary plexus infiltrated with leukocytes during inflammation of the tympanic membrane in man, degenerative changes occurred in the capillary nerves. With the appearance of leukocytes in the neuroplasm of the sheaths, a granular disintegration of the neurofibrillary substance of the nonmedullated nerve fibers was seen. Poor impregnation of the axis-cylinders with silver was also observed. A proliferative tendency of the neuroplasm coincident with raising the continuity of the neurofibrils was evident. This was recognized by loosening of the structure of the nerve sheaths as well as the lemmoblast nuclei. This process appears to be able to go so far that the fibrous tissue elements which surround the capillary nerves can enter into the structure of the degenerating sheaths.

EDITOR'S ABSTRACT.

ETIOLOGY AND THERAPY OF MÉNIÈRE'S DISEASE. H. JUST, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:171 (Feb. 10) 1934.

Just believes that Ménière's symptom complex is nothing more than an angioneurosis especially of the acoustic nerve. He states that he has never seen active or latent Ménière's disease without unilateral or bilateral infection in the upper air passages and that the symptoms promptly disappear when the nasal condition is cured. Acute or chronic catarrh in the upper air passages, especially the sphenoethmoid recess, and catarrh or purulent infection of the sphenoid sinuses or ethmoid cells are the most common etiologic factors. Decrease in acuity or hearing and a constant sensation of noise indicate permanent damage in the region of the nucleus of the cochlear nerve. Relapses after treatment of the underlying nasal conditions do occur. It stands to reason that new infections of the mucosa of the upper air passages in the course of influenza or other catarrhal infections may bring on a new attack of Ménière's syndrome On prophylactic grounds, Just feels that persons disposed to catarrh should be given small amounts of iodide.

EDITOR'S ABSTRACT.

TRANSCONCHAL RADICAL OPERATION ON THE EAR. E. MATIS, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:181 (Feb. 10) 1934.

Matis has devised a new radical operation for diseases of the middle ear. Local anesthesia is usually sufficient. A curved incision is made in the middle of the cavum conchae, extending from the anterior incisura auris to the incisura intertragica. After detachment of the wall of the external ear and the pinna, a speculum is inserted and the bleeding stopped. The cortex thus freed behind, the outer ear passage is chiseled away to a depth of about 1.5 cm. The antrum is then sought, to which the upper and back walls of the auditory canal serve as guide. The antrum is widened posteriorly, and all infected cells are removed. Communication with the exterior is created by a wide hole to the outer ear. Great care is used not to injure the tympanic membrane or the auditory ossicles. A wide pedunculated plastic flap is built from the posterior wall of the auditory canal and a part of the cavum conchae, which is laid over the opening toward the back. The author feels that this operation has several advantages. It is technically easy and can be performed with usual instruments, and the field is always open to binocular vision. Radical operation can be easily performed. Scar formation is relatively slight, the sound wave apparatus is not much damaged and the function of the ear is rarely unfavorably affected. Postoperative pain is rarely observed. The cosmetic effect is also good.

EDITOR'S ABSTRACT.

SUDDEN FRACTURE OF THE LABYRINTH. H. BARTH, Ztschr. f. Laryng., Rhin., Otol. (Teil 1: Folia oto-laryng.) **24**:373, 1933.

An unusual case of acute otitis media that developed rapidly (five days) into labyrinthitis and purulent meningitis is presented by Barth. There was a fracture of the bony labyrinth on the side opposite to that on which the otitis occurred. No cause for this could be found in the history, and it is suggested that it may have occurred when the patient was having symptoms of motor disturbance caused by the meningitis.

EDITOR'S ABSTRACT.

Pharynx

TONSILLECTOMY AND PERITONSILLAR ABSCESS. G. HOFER and T. MOTLOCH, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:390 (April 6) 1934.

Hofer and Motloch review the danger of performing tonsillectomy in the face of peritonsillar abscesses. The importance of this question is due to several factors. Simple incision in cases in which the abscess lies posteriorly and deep is often insufficient, the pus draining poorly through the incision. Hemorrhage into the abscess cavity from the incision wound occurs not infrequently. The tonsils sometimes act like a foreign body in preventing complete drainage of the abscess. In

diffuse phlegmonous processes wide open incision and drainage only will suffice. In more than thirty patients with peritonsillar abscesses, operated on at various stages, only slight local reaction occurred and no glandular swelling or severe pain was observed after the operation. With one exception a drop in temperature occurred soon after the procedure. These results compared favorably with those of tonsillectomies performed for chronic recurrent tonsillitis and of operations done two fever-free days after acute tonsillitis. The authors, therefore, conclude that not only is tonsillectomy for peritonsillar abscess relatively free from danger, but it is the procedure of choice.

EDITOR'S ABSTRACT

CONTRAST ROENTGENOGRAPHIC STUDIES OF THE NASOPHARYNX. L. RÜEDI and A. ZUPPINGER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:500 (April 6) 1934.

A technic for improving the study of the nasopharynx is described by Rüedi and Zuppinger. The soft palate and posterior pharyngeal wall are first anesthetized in the usual way. The contrast fluid is injected and the pictures are taken with the head hanging down. The fluid is injected behind the soft palate or preferably by means of a flexible catheter into the nasopharynx. Iodized poppy-seed oil 40 per cent seems to be the best fluid for this purpose, and about 12 or 15 cc. is used. Two views are taken of the hanging head. With a turned half axial view the central rays are directed at the chin and external auditory canal; the side view centers on the external auditory canal. The turned half axial view normally shows on both sides wide stripes of the contrast medium, with nearly parallel border contours. Toward the mesopharynx the shadows gradually recede. In the anterior nasal region the smooth contours are broken by the conchae. The septum can be seen in the middle. Occasionally, in the region of the epipharynx, two symmetrical, sharply circumscribed humps can be seen which represent Rosenmüller's fossae. The roentgenogram thus produces topographic evidence which is lacking to the unaided eye. This simple procedure establishes in every case the space-limiting process and gives definite evidence of the place, form and extensiveness of the change. The kind of process cannot be definitely established by the roentgenogram; in general smooth, regular contours speak for a benign tumor, but biopsy and histologic examination are essential. The authors recommend this procedure as a considerable diagnostic aid.

EDITOR'S ABSTRACT.

Nose

THE SUBPERIOSTEAL VESTIBULONASAL OPERATIVE METHOD: A NEW OPERATIVE PROCEDURE FOR DISEASE OF THE NASAL ACCESSORY SINUSES. E. MATIS, Monatschr. f. Ohrenh. **68**:427 (April) 1934.

Matis' operative method, previously described in detail for the frontal sinus, is extended in this paper to other sinuses. For the sphenoid sinus the subperiosteal method widens the operative field and shortens the route. In addition, radical cleansing of the anterior sphenoid wall is made possible. Especially important from the standpoint of technic is the free resection of the frontal process. Diseased walls of the ethmoid cells may be similarly freely removed. Combined accessory sinus empyema, although rarely treated by operation, may be advantageously attacked by this technic. The operative incision in the nasal vestibule, the subperiosteal loosening of the soft tissue and the resection of the frontal process remain the same for all the subperiosteal vestibulonasal operations. After local anesthesia of the operative incision at the piriform aperture and loosening of the soft tissue of the middle and upper orbital wall, the technic for operation on the frontal sinus involves opening the sinus above the tear duct fossa, resection of the floor of the sinus and resection of the frontal process with the object of forming a wide passage between the frontal sinus and the nose. For the ethmoid cells resection of the frontal process and the laryngeal bone and cleaning out of the cells are undertaken. Similar methods are followed for the sphenoid sinus. For

pansinusitis a combined operation involving the Sturmann-Canfield method for the antrum and the author's method for the other sinuses is applied. The subperiosteal vestibulonasal method is assigned the following advantages by the author: No external incision is made, whereby visible scars, fistula formation and postoperative neuralgias are avoided. The procedure is more visible and more radical than previously described endonasal operations. Postoperative treatment of the sinuses operated on involves short drainage. Also the entrance to the sinuses may be kept open for a long time. It saves the healthy tissue, especially the soft tissue and periosteum, which are especially favorable to rapid healing.

EDITOR'S ABSTRACT.

A CASE OF FATAL MENINGITIS AFTER INTRANASAL OPERATION ON THE ETHMOID. O. MAYER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:377 (April 6) 1934.

The case of a woman, aged 30, is described by Mayer. Under local anesthesia a submucous resection was performed on a deviated septum. The ethmoid was then opened, found to be filled with polyps and cleaned out. Finally the anterior ethmoid cells on the left were opened and polyps removed. At this point the patient suddenly experienced pain. Lateral to the anterior portion of the cribriform plate a three-cornered tear of the dura mater, from which fluid poured, could be seen. Iodoform powder was immediately blown on this region, and a dry iodoform gauze pack inserted. However, the patient died in four days as a result of purulent meningitis. At necropsy the ethmoid was removed from the body and, after fixing, decalcification and embedding, examined in serial section. The thinness of the trabeculae of the bone, especially of the ethmoid roof, was worthy of note. The case shows, according to the author, that if one goes lateral to the middle concha, cleaning out the ethmoid is dangerous. The impression that radical cleansing of the ethmoid from the nose is not dangerous is false. The plane of the lamina cribrosa both above and lateral to the middle concha should not be crossed in order to avoid injury of the ethmoid roof.

EDITOR'S ABSTRACT.

MORPHOLOGY OF HUSCHKE'S CARTILAGE. H. RICHTER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:415 (April 6) 1934.

Richter studied the comparative anatomy and development of Huschke's cartilage in sheep, guinea-pigs, orang-utans and human beings. His method was to make enlarged wax models. The first model was from a sheep embryo of 4.2 cm. vertex-breech length. The second was from a guinea-pig embryo of 3 cm. vertex-breech length. The third was from an orang-utan embryo of 18 cm. vertex-breech length. From these three mammalians it was determined that (1) the form of Huschke's cartilage in mammalians differs; (2) the cartilage in the lower mammalians is of less complicated structure than that in the orang-utan, and (3) the Huschke cartilage in mammals is built symmetrically on either side of the septal cartilage.

The author also made nine models from human beings in different stages of development. This series showed that in general in man only one Huschke cartilage is on each side of the septal cartilage, to which it is not attached. Attachment of the Huschke cartilage to the septal cartilage was observed only once in this series. He concludes that in man the symmetry of the two cartilages decreases with advancing fetal development; the single processes of the cartilaginous plate reach their height about the sixth fetal month, after which involution sets in, and the primary form of the cartilaginous plate also makes changes which speak for its involution. Up to the fifth month, then, the two Huschke cartilages grow approximately equally, but after that time the continuous and parallel growth ceases.

EDITOR'S ABSTRACT.

TEMPORARY AMAUROSIS WITH ANESTHESIA OF THE SEPTUM. L. LEDERER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:452 (April 6) 1934.

Three cases of temporary blindness occurring during anesthetization of the septum are discussed by Lederer. Two of these have been previously reported by others. In the author's own case the patient experienced a sudden flushing of the right eye associated with a feeling of swelling from the back of the eye. This occurred during the injection of 1 per cent solution of procaine hydrochloride with epinephrine on the right side fairly deep in the nose and behind and above the middle concha into the subperiosteum. For a few seconds the patient was completely blind. Soon vision returned in the left eye. In about ten minutes light was again perceived by the right eye. Double vision existed for some time with the clearer image seen by the left eye. The eyegrounds revealed no abnormalities. For several hours prolonged use of the right eye caused pain, but this also finally disappeared in a few days. The author discusses the chief possible explanations. He feels that the most likely is a direct transfer of the injected substance by way of the posterior ethmoid artery and the ophthalmic artery into the central retinal artery. This route is anatomically direct as a rule. EDITOR'S ABSTRACT.

Miscellaneous

ERYSIPELAS AND THE HEMOLYTIC STREPTOCOCCUS IN RELATION TO OTOLARYNGOLOGY. D. MCKENZIE, J. Laryng. & Otol. **49**:105 (Feb.) 1934.

McKenzie believes that a new infectious disease is becoming recognized. When erysipelas appears in the wards it may arise from another case of erysipelas, from a streptococcic infection not erysipelas in another person or from a streptococcic infection not erysipelas in the patient himself. Clean operative wounds are more liable to the infection than those already septic. Nonoperative erysipelas often starts in the nose, and it also extends to the nasal interior from the face, giving rise to much swelling of the turbinals and mucosa. Erysipelas starting in the external auditory meatus secondary to an acute suppuration of the middle ear is uncommon apart from operation, though the author reports one such case. Surgical erysipelas is more dangerous to life than the spontaneous variety. Bacteriologists are inclined to be timid with regard to the tonsils because hemolytic streptococci are so frequently present. Septic infections occur less often after tonsillectomy, however, than after any other otolaryngologic operation. The exogenous streptococcus is the most dangerous. The author believes that in view of present knowledge patients with clean operative wounds should be separated in the wards from those with active streptococcic infections. Sore throat among members of the hospital staff is also particularly dangerous. In regard to the relation between scarlet fever and erysipelas the author suggests that since the streptococcus of scarlet fever attacks the pharynx primarily and that of erysipelas the skin, the absence of mutual immunity may depend on these differences rather than on any specific and stereotyped differences in the streptococci themselves.

EDITOR'S ABSTRACT.

SOFT ODONTOMA OF THE MAXILLARY BONE. L. HÖRBST, Arch. f. Ohrenh-, Nasen- u. Kehlkopfh. **138**:30 (March) 1934.

Hörbst describes the case of a girl, aged 9, who for four months had been afflicted with a tumor-like swelling of the left superior maxilla. Recovery followed operative removal of this tumor. Histologic examination of the tumor showed a general structure consisting of numerous rudimentary dental anlagen lying side by side. These were composed of embryonic connective tissue bordered by mantle-like proliferations of epithelial cells. Between the anlagen of various form and size lay a cell-poor spongy connective tissue stroma. This was poorly developed, and the germ cells were encountered in different levels of the section. Under

greater magnification these germ cells showed great similarity. They were constructed of epithelium and embryonic pulp tissue in such a manner that first one and then the other was more conspicuous. The epithelial portions of the tumor lay partly regularly embedded in the supporting tissue and partly divided into groups. In the supporting tissue specific eosin-red matrix was lacking. In summary, the essential histologic picture was that of a dental tumor consisting principally of rudimentary dental germ cells. This tumor must therefore be classified as a rare soft odontoma.

EDITOR'S ABSTRACT.

BILATERAL SYMMETRICAL MYELOMA OF THE TEMPORAL BONE AND PARIETAL BONE. E. BRUCH, Arch. f. Ohren-, Nasen- u. Kehlkopfh. **138**:37 (March) 1934.

Bruch describes the case of a girl, aged 3¼ years, with a myeloma involving successively the left and the right temporal and parietal bones. The lesion was operated on on both sides. The histologic picture showed the structure of a myeloma rich in blood vessels. The nuclei were rounded, and giant cells were present. Diabetes insipidus developed later, probably as a result of metastasis, but the patient was living at the time the report was written. Inspection of the tympanic membrane and hearing tests were impracticable because of the refractory condition of the child.

EDITOR'S ABSTRACT.

ACID-COMBINING POWER OF THE CEREBROSPINAL FLUID. K. LÖWY, Monatschr. f. Ohrenh. **68**:221 (Feb.) 1934.

Löwy describes a method of measuring the acid-combining power of the cerebrospinal fluid by means of a rheostat apparatus with a capillary electrometer. By this means the maximum acid-combining power of normal cerebrospinal fluid was found to average 2.20×10^{-2}. The "middle basic dissociation constant" was about 5.0×10^{-8}. The most important acid-combining element of the fluid is bicarbonate. Possibly also waste nitrogenous substances have a small basic function.

EDITOR'S ABSTRACT.

ONE-SIDED DISTURBANCES OF THE POSTERIOR CRANIAL NERVES. A. I. GESCHELIN, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:159 (Feb. 10) 1934.

Geschelin describes the case of a patient, aged 53, with signs and symptoms of a disorder of the nuclei of the last five cranial nerves of the left side. The iris of the left eye was more deeply pigmented than the right. The left eye did not converge inwardly quite normally. There was decreased strength in the left masseter muscle. There was atrophy of the left orbicularis oris muscle. There was decreased touch and pain sensation of the left side of the tongue and palate. There was paresis of the left palatine arch. The left sternocleidomastoid muscle was not palpable. The tongue protruded to the left, and there was atrophy of the left half. Hearing was much diminished on the left, but the vestibular apparatus was normal. The diagnosis was syringobulbia. The author cites this case as being similar to Collet's syndrome and differing from it chiefly in the involvement of the acoustic nerve.

EDITOR'S ABSTRACT.

TREATMENT OF BRONCHIAL CARCINOMA. VON EICKEN and A. ADAM, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:231 (March 12) 1934.

Von Eicken and Adam believe that early diagnosis and proper choice of treatment of bronchial carcinoma allow an important improvement to occur in many instances. The roentgenograms are not a sufficient basis for diagnosis. The clinical history and the results of physical examination, bronchoscopy and exploratory thoracotomy are important adjuncts. The best treatment is afforded by the operative procedure. Total extirpation of a lung or extirpation of a lobe of one

lung with removal of the tumor on the other side by means of the bronchoscope is sometimes indicated. After the removal of a tumor by the bronchoscope, intrabronchial roentgen treatment is advisable. An additional transthoracic roentgen treatment may be given for the regional lymph nodes. EDITOR'S ABSTRACT.

FREQUENCY AND COURSE OF MELANOSARCOMA OF THE UPPER RESPIRATORY AND DIGESTIVE TRACTS. W. SCHIBLER, Ztschr. f. Hals-, Nasen- u. Ohrenh. **35**:241 (March 12) 1934.

Schibler states that of more than 120,000 patients seen in the Basel otolaryngologic clinic and polyclinic during the last thirty-six years, there were only 3 with melanosarcoma. One tumor was in the nose, one in the alveolar process of the upper jaw and one in the right tonsil. In going through the literature he found reports of only 89 cases of primary melanosarcoma of the upper respiratory passages. In these cases, 42.7 per cent of the growths were in the nose or accessory sinuses, 47.1 per cent in the oral cavity, especially the hard and soft palate, 3.3 per cent in the throat, 2.2 per cent in the palatine tonsils, and 4.4 per cent in the esophagus. Primary melanosarcoma of the larynx has never been described to the author's knowledge. In 12 of the reported cases of melanosarcoma of the nasal cavities, the age and sex of the patient were not known. Of the remaining cases, 16 occurred in women and 10 in men. The ages ranged from 32 to 81 years, the average being 54. Apparently this condition is unknown in children. Operative treatment has not given favorable results and usually one or two years is the duration of life. In one of the author's cases roentgen therapy was used, but no improvement resulted.

EDITOR'S ABSTRACT.

SEPSIS AFTER SCARLET FEVER AND DIPHTHERIA AND ITS TREATMENT. H. CLAUS, Ztschr. f. Laryng., Rhin., Otol. (Teil 1: Folio oto-laryng.) **25**:8, 1934.

Sepsis, according to Claus, in the Schottmüller sense, means a periodic or continuous invasion of the blood stream by pathogenic organisms from a focus, from which objective and subjective signs of generalized illness result. Though this condition is relatively rare in scarlet fever, it does occur. The author cites six such cases involving venous thrombi in patients on whom he was called to operate. Thrombi were found in one or more of the jugular or facial veins and treated by ligature above and below. Recovery occurred in four cases and death in two. In the fatal cases, however, it was not possible to isolate the thrombi successfully. A similar mixed infection thrombus developed in a patient with diphtheria in whom infarction of the lung had already occurred. There was eventual recovery. Although this procedure is not a common necessity, the author feels that it promises the saving of some patients with otherwise hopeless cases.

EDITOR'S ABSTRACT.

A CASE OF NONPURULENT LATERAL PERICHONDRITIS OF THE THYROID CARTILAGE. G. BOENNINGHAUS, Ztschr. f. Laryng., Rhin., Otol. (Teil 1: Folio oto-laryng.) **25**:18, 1934.

Perichondritis of the lateral portion of the thyroid cartilage is rare, certainly more rare than that of the anterior part. Boenninghaus describes a case in a man, aged 41, in whom a swelling of the arytenoid in the form of a sterile abscess of the mucosa developed following parotitis, probably nonepidemic. This abscess eventually ruptured and healed without intervention. To this infection was joined a similar one of the perichondrium involving both the inner and outer layers of the thyroid cartilage. Contrary to expectation, no abscess formation resulted from the perichondritis of either side, but complete healing occurred. It was possible to observe the course of the perichondritis with the laryngoscope from the time of greatest involvement almost to complete return to normal. Because of these

observations and others made previously in cases of lateral perichondritis of various origin, the author concludes that every case of lateral perichondritis possesses a characteristic laryngoscopic picture. This is flattening and widening of the sinus piriformis without swelling of the epiglottis or the aryepiglottic fold.

EDITOR'S ABSTRACT.

DIAGNOSIS AND TREATMENT OF OSTEITIS FIBROSA OF THE FACIAL PORTION OF THE SKULL. W. KINDLER, Ztschr. f. Laryng., Rhin., Otol. (Teil 1: Folio oto-laryng.) **25**:54, 1934.

Kindler describes two cases of circumscribed osteitis fibrosa of the facial portion of the skull. In the first case, a malignant tumor in the neighborhood of the right maxilla was diagnosed, but histologic examination of tissue removed at biopsy showed the typical picture of osteitis fibrosa with fibrous marrow, a mosaic structure with early periosteal hypertrophy and lacunar resorptive processes. The second case, in a woman aged 44, involved the hard palate and molar teeth, so that disturbances in chewing became the principal subjective symptom. An extensive maxillary cyst arising from the dental system, osteoma and sarcoma are the principal differential diagnostic possibilities. Both patients were much improved by roentgen therapy.

EDITOR'S ABSTRACT.

Society Transactions

AMERICAN LARYNGOLOGICAL, RHINOLOGICAL AND OTOLOGICAL SOCIETY

E. W. Hagens, M.D., Chicago, *Abstract Editor*

Fortieth Annual Meeting, Charleston, S. C., April 3-5, 1934

J. W. Jervey, M.D., Greenville, S. C., *President*

Nutritional Influences. Dr. William Weston, Columbia, S. C.

Dr. Weston discussed the effects of mass dietary factors as observed in the Japanese people. It is probable that the Japanese come nearer to adhering to what is understood as a satisfactory diet than any other people in the world. As a result, they exhibit such characteristics as mental alertness, great energy, remarkable physical strength and extraordinary endurance.

The author reviewed the knowledge of the effects of diet on the mucous membranes and the special senses. He emphasized the relation of certain mineral elements to the utilization of other mineral elements by the body. In conclusion, he made the point that it is neither necessary nor advisable to resort to artificial sources for the materials from which to select the diet.

Sympathetic Influences (Autonomic Level). Dr. Francis B. Blackmore, Columbus, Ga.

There are two antagonistic parts of the autonomic nervous system. One may visualize extreme sympathetic dominance at a high level and extreme parasympathetic dominance at a low level. Then the condition of a patient at a given time can be indicated as being at some level between these two. Such a level is named the autonomic level by Dr. Blackmore.

Symptoms and signs characteristic of each type of displacement are recognized. Numerous factors exerting displacing force in each direction have been observed. When properly selected and applied to the patient, these factors will exert force toward the establishment of a normal equilibrium. The work of Jarvis, using the red or pale septum as an indicator, is of great aid and importance in classifying a given patient's condition.

Insulin Therapy. Dr. Samuel M. Beale, Sandwich, Mass.

Dr. Beale discussed a series of clinical observations of the action of insulin, beginning with the improved growth of a toe-nail in a diabetic patient. This suggested its usefulness in cases of sclerotic disease—cell degeneration. Further observations were made in cases of cell perversions—benign and malignant growths —and of defects of calcium metabolism. The application of all the data was made to otology, rhinology and laryngology.

DISCUSSION

Dr. D. C. Jarvis, Barre, Vt.: These newer clinical approaches in otolaryngology bring home anew the relationship existing between symptoms of disturbance of the upper respiratory tract and those of systemic dysfunction. The chemical content of the patient's food is of primary interest. An excess of potassium and iodine in organic form produces a watery nasal discharge. With too much sodium chloride a dry nose develops.

In regard to Dr. Blackmore's paper, one has been more or less familiar with facts relating to the autonomic nervous system, but the difficulty has been in applying these facts clinically. One expects the infections to be associated with a dominant sympathetic system and the allergies with a dominant parasympathetic system. When the sympathetic system is dominant, iodine in some form seems to be the therapeutic agent of choice, and when the parasympathetic system is dominant, dilute hydrochloric acid is indicated.

Dr. Beale's work opens a whole new chapter in otolaryngology. Ulceration of tissue, mucopurulent discharge, scab formation within the nose and new growths are all seen in the light of a low tolerance to carbohydrates. In some cases, the carbohydrate intake is kept low during postoperative convalescence; in others, in addition, powdered spinach is added to the diet, while in a third group, showing dried nasal secretions, 4 units of insulin daily is advised. Under such treatment the nasal secretion disappears.

DR. IRA FRANK, Chicago: Dr. Weston's paper supplies much food for thought. I am greatly impressed by the large number of poisonous fungi which may be found in cereals. Deficiency of the vitamins as a cause of various conditions has been stressed. As Dr. Weston suggests, an insufficient supply of vitamin D may cause a malformation of the malleus, incus and stapes.

Dr. Blackmore's paper is particularly interesting to me because it deals with the pale septum which I have previously discussed as possibly affording some hint of faulty body chemistry. I have found the pale septum to have suggestive value in diagnosis and in treatment, but I realize that a vast amount of work remains to be done on the subject before one can be sure that one knows whereof one speaks. Clinical records should contain notations of the color index of the septal mucosa, the patient's alkali reserve and the carbon dioxide tension and hydrogen ion concentration of the blood.

DR. T. W. MOORE, Huntington, W. Va.: Dr. Weston has shown how the mineral and vitamin properties of milk may vary greatly. His paper shatters many of my idols in a most convincing manner.

Dr. Beale's paper astounds one with the number of varied diseases in which he has found insulin useful. I agree with Dr. Beale's suggestion that primitive peoples are free from cancer and that this is probably due to the kind of food eaten and its method of preparation. Has Dr. Beale any guide in the administration of insulin? Has he not observed cases in which hyperinsulinism developed?

DR. JOHN F. BARNHILL, Miami Beach, Fla.: Dr. Weston gave beautifully the story of the refugees from the United States who went to Canada and those who went to the Bahama Islands or to the Caribbean Islands. He said that the health of those in Canada was much better and their mentality much better than that of those in the Caribbean Islands. But their environment was not taken into account. In the Caribbean Islands 95 per cent of the inhabitants are Africans, and the mentality of the refugees was not likely to develop as it would among the Canadians. Further, in the Caribbean Islands there is little of what is known as modern sanitation. Also, the people eat only fish, bananas and grapefruit.

DR. H. M. TAYLOR, Jacksonville, Fla.: Dr. Taylor read a letter from a grateful patient who was relieved by the regimen on which he was placed for sneezing, postnasal dripping, bad breath, etc., and extreme redness of the nasal membrane. Alkalis, spintrate (a dry spinach preparation) and green vegetables were emphasized. The amounts of carbohydrates and meat were decreased.

DR. WILLIAM WESTON, Columbia, S. C.: I have been particularly interested in the iodine content of food because a study of this subject has revealed that iodine has been an important element in the diet of all the people who have achieved greatness and of the nations that have survived. It is important to know that it is only from the organic form of any element that one receives its ultimate benefit. The food must contain a sufficient amount of amino-acid tyrosine in order that inorganic iodine may be as effective as its organic form. If the diet contains a

sufficient amount of iodine, one can get a perfect balance of calcium, phosphorus and magnesium, and in no other way can this be achieved. By proper diet the American people may rise to their utmost efficiency, regardless of their origin.

Dr. Francis B. Blackmore, Columbus, Ga.: I wish to emphasize that one has not paid sufficient attention to the observations of the old clinicians. I advise the reading of Dr. Cannon's book entitled "Bodily Changes in Pain, Hunger, Fear and Rage."

Dr. Samuel M. Beale, Sandwich, Mass.: The question was raised as to whether deleterious effects result from persistent use of insulin in nondiabetic patients, and I shall have to say yes. The dose is small, however, and the dangers are small in proportion. The primary effect is on the endocrine glands, and the effect on the blood sugar is secondary.

Accidental Injury of the Lateral (Transverse) Sinus During Mastoidectomy. Dr. Henry Dintenfass, Philadelphia.

An effort has been made to study and correlate data concerning accidental injuries of the lateral sinus during mastoidectomy. Injury of the lateral sinus increases the risk of the operation.

When the mastoid is large and pneumatic, the space between the lateral sinus and the posterior wall of the canal is broad; injuries of the sinus are less apt to occur, therefore, than in the small sclerotic mastoid, where the space between these structures is narrow. Injuries to the sinus appear to be more frequent in the right mastoid in men and in the left mastoid in women. Absence of the sinus plate or adhesions of the sinus to surrounding structures predispose to injury.

The employment of the curet in removal of bone is more likely to be accompanied by trauma to the lateral sinus than is the use of any other instrument. The use of the gouge is attended with least danger. It seems wise to avoid the use of curets, especially the narrower ones, when removing bone in close proximity to the sinus.

Bone in the immediate vicinity of the sinus should be removed last in all operations on the mastoid for if the sinus is traumatized the danger of infection is less, all the diseased tissue with infecting bacteria having been removed. There is also the advantage that the operative procedure will not be interrupted by hemorrhage.

The principal complications of injury to the sinus are hemorrhage, secondary rupture of the sinus, septic thrombophlebitis and air embolism. Infection following injury of the sinus is usually due to the virulence of the organism of the diseased tissues. Infrequent change of packing is another contributing factor. Thrombi in the lateral sinus following accidental injury may become organized and remain so, or they may disappear spontaneously by secondary absorption, the sinus regaining its patency.

The treatment of injury to the sinus consists primarily of arresting hemorrhage by placing tampons in the operative cavity, and then obliterating the lumen of the sinus by introducing gauze between the sinus and its bony covering above and below the site of injury. Infections of the blood stream should be controlled by intravenous medication, blood transfusions and ligation of the jugular vein.

It is probable that the occurrence of septic thrombophlebitis following mastoidectomy is a sequel, in some instances, of accidental injury of the sinus not recognized at operation.

DISCUSSION

Dr. David N. Husik, Philadelphia: I am heartily in accord with all that Dr. Dintenfass has said. I do not think that the linea temporalis is a good surgical landmark for the location of the lateral sinus. X-ray plates, however, tell the position of the sinus. I do not uncover the sinus unless there is a suspicion of a thrombus. The sinus may be injured in any operation on the mastoid, as it may be very superficial. If it is injured, the hemorrhage should be controlled by packing.

Dr. Horace Williams, Philadelphia: One wonders that the lateral sinus is not injured more often. My opinion has always been that there are no ill effects from removal of the sinus plate provided there is no injury to the sinus.

Dr. C. McDougall, Atlanta, Ga.: In my twenty years of private practice I have learned not to uncover great areas of the sinus. I think that the more the sinus is uncovered the greater the chance for infection. I have had the misfortune to puncture 2 sinuses in private practice. In 1 case the wound healed over without complications; but in the other case the patient finally died, and at postmortem examination a clot was found in the longitudinal sinus.

Dr. Henry Dintenfass, Philadelphia: In the majority of cases an oblique position of the linea temporalis always means a narrow mastoid, and a narrow mastoid always indicates a forward position of the lateral sinus. I have observed several cases in which the lumen of the sinus has been restored following thrombosis of the vessels, as proved by autopsy.

Laryngopulmonary Tuberculosis: A Review Based on Twenty Years' Experience. Dr. J. P. Dworetzsky, Liberty, N. Y.

Tuberculosis of the larynx should be considered as a complication of pulmonary tuberculosis and should never be viewed or treated as a clinical entity. The treatment of laryngopulmonary tuberculosis should consist mainly of the treatment of the parent lesion, that is, the pulmonary disease. Collapse therapy, which is the most valuable measure in the treatment of pulmonary tuberculosis when successful, not only will prevent the development of laryngeal tuberculosis but will promote healing of a coexisting laryngeal lesion.

A group of 500 cases of pulmonary tuberculosis were examined and compared with the fairly similar group of 500 cases examined twenty years ago. Whereas the incidence of laryngeal tuberculosis in 1914 was 25.6 per cent, the incidence in 1934 was found to be 14.6 per cent. This pronounced reduction of the occurrence of laryngeal tuberculosis can readily be explained by the improved methods of diagnosis and the consequent earlier application of treatment, and also by the improved methods of treatment. Whereas collapse therapy was not employed in any of the cases studied in 1914, it was employed in 20 per cent of the cases of the present group.

DISCUSSION

Dr. Thomas E. Carmody, Denver: I do not believe that one ever sees primary tuberculosis of the larynx. The cases that have been reported as instances of that condition have not been thoroughly examined. As a rule, in cases of progressive tuberculosis of the larynx, one finds progressive pulmonary tuberculosis. In the diagnosis of tuberculosis of the larynx there is no question but that other diseases of the larynx may also be present, such as cancer, syphilis, etc.

That pulmonary lesions are treated better today than they were twenty years ago is the reason that laryngeal disease is less frequent. In the local treatment, sprays are of little value except for cleansing. Artificial pneumothorax is of great value; however, the use of sunlight and artificial sunlight has been overdone. Cautery does a great deal of good, but for the removal of the epiglottis and other operations of that kind one rarely uses it today.

Dr. E. A. Looper, Baltimore: At the Maryland State Sanatorium my associates and I have discontinued the use of all chemical caustics and have found cauterization most satisfactory in properly selected cases and when general treatment of the pulmonary lesion is actively carried out.

It is unfortunate that such a pessimistic general opinion persists in regard to the treatment of laryngeal tuberculosis. If recognized early, most of the lesions may be cured. Of 3,227 patients at the Maryland State Sanatorium in 1928, 15.5 per cent had laryngeal lesions. By the use of the cautery we have been able to improve or cure 65.5 per cent of the patients who had moderate pulmonary involvement and to improve 26.5 per cent of those with far advanced pulmonary involvement.

DR. PERRY G. GOLDSMITH, Toronto, Canada: I think that there is a great deal of looseness in the diagnosis of tuberculosis of the larynx. A person who has tuberculosis of the larynx always has a change in the mucous membrane of the pharynx, a redness and inflammation, and the same condition is present in the trachea. To justify a diagnosis of tuberculosis of the larynx there must be infiltration and ulceration.

I am not quite prepared to accept the statement that collapse therapy prevents laryngeal tuberculosis.

As to treatment, if a patient has progressive tuberculosis, copious sputum and diffuse lesions of the larynx, one should leave the larynx alone. A tracheotomy is a godsend in advanced cases with edema. Local treatment has long been given up except in the form of the disease in which the cautery is used. Cautery is not advisable in progressive laryngeal tuberculosis. A patient with this form will die of the pulmonary condition or of the general condition. Vocal rest in cases of laryngeal lesions is essential. I have not had much experience with heliotherapy. I do not use it.

DR. JULIUS P. DWORETZKY, Liberty, N. Y.: I do not think there is much doubt that collapse therapy prevents laryngeal tuberculosis. Occasionally, my associates and I have to do a tracheotomy, but we have a great deal of trouble with it.

AURAL TUBERCULOSIS (CANDIDATE'S THESIS). DR. JOHN MILLER, Greenwich, Conn.

This paper will be published in full in a later issue of the ARCHIVES.

DISCUSSION

DR. JAMES G. DWYER, New York: My interest has been from the pathologic standpoint, in trying to develop a method of isolating the organism directly by culture. Examination of tissue from the ear is unsatisfactory. Furthermore, I do not think that it is a good policy to cut the tissue out for examination. I have used the method of planting the culture by direct isolation, as described by Petroff.

I think that most of the infections are carried through the blood stream or through the lymphatics, and not through the eustachian tube. In children, the aural infection is not secondary to a pulmonary lesion, and the organism is usually of the bovine type. In 1916 or 1917, St. Clair Thomson made the statement that he had never seen caries of the ear, and that he had never seen ossicles coming out, facial paralysis or multiple perforation. My experience is directly opposite to that.

DR. J. P. DWORETZKY, Liberty, N. Y.: My experience with tuberculosis of the middle ear has been limited to adult patients. I can recall many instances in which tuberculosis of the middle ear healed with improvement in the pulmonary lesion. Three cases are cited to substantiate this.

DR. H. B. GRAHAM, San Francisco: The best description of tuberculosis of the ear from a pathologic standpoint was that given about 1913 by Ribbert of the German Otological Society. The essayist did not mention the fungoid and the gangrenous forms of aural tuberculosis. In the latter type the bone is dry and black. The bovine form in children is not as dangerous as aural tuberculosis in adults due to the human bacillus. When the infection is cleared out the child gets entirely well.

DR. H. G. PRESTON, Harrisburg, Va.: In regard to extrapulmonary tuberculosis, one must keep in mind the relationship of allergy to the organism itself rather than to the invasion of the tissues by the organism.

DR. EDMUND P. FOWLER, New York: My associates and I examined from 450 to 500 patients several years ago in a large hospital for tuberculous patients. Our statistics as to the effect on the hearing did not exactly tally with those reported today. In fact, in our series the hearing was remarkably good.

THE EFFECT OF SEVERE ILLNESS ON THE HEARING. DR. EDMUND PRINCE FOWLER, New York.

It seems logical to believe that severe illness should cause some disturbance in function in all sense organs, particularly in so fine and intricate an apparatus as the auditory organs. To determine what effect, if any, a severe illness has on the hearing, Dr. Fowler examined over 1,000 hospital patients and grouped them according to the diseases from which they suffered. Because of the overabundance of material his discussion at this time was limited to one disease, namely arteriosclerosis.

To visualize the data better the 167 patients with this condition were divided into five groups representing the five decades from 30 to 80 years, inclusive. Air conduction and bone conduction tests were made with the 2A Western Electric audiometer. Although the number of normal results obtained made it apparent that the ever-present noises seldom interfere with accuracy, it was considered that a loss of hearing of 10 sensation units should be counted as indicating no loss.

The results for twenty patients with fractures and the averages of Bunch and Raiford for all hospital patients in four decades from 30 to 70 years of age, inclusive, were used as controls. Bunch's averages for 137 patients with arteriosclerosis were also used. Bunch omitted the tests on persons in the eighth decade by bone conduction in his report, and he included the worse ears.

Dr. Fowler showed the proportional losses both by air conduction and by bone conduction, the air conduction at frequencies of 256, 1,024, 4,096 and 8,192 vibrations and the bone conduction at frequencies of 256, 1,024 and 4,096 vibrations. This has not heretofore been done. He found the bone conduction as measured by the audiometer quite reliable, notably in ears with obstructive lesions. Rarely was bone conduction found to be less than air conduction, "which fact alone proves its relative value as a quantitative measure of inner ear, nerve and central functioning."

Various methods of tabulating were described, and two tables were shown presenting losses in air and in bone conduction at all the frequencies and in the five decades.

The author found that age alone is not the cause of deafness. If it were, how would one account for the old people with normal hearing?

The author demonstrated that the bone conduction percentages give a truer picture of the nature of the deafness in arteriosclerosis than do the air conduction percentages. Photomicrographs of petrous bones were shown in correlation with the data on acuity of hearing.

It was pointed out that arteriosclerosis is a patchy disease and that if found in one place it need not be present in distant or even nearby places. Even in cases of generalized arteriosclerosis one cannot be certain of finding arteriosclerosis in the ears, but if there are progressive losses of hearing by air conduction and bone conduction the author's studies seem to indicate that arteriosclerosis of the ears is likely to be responsible, other causes being eliminated. Contrariwise, the absence of progressive losses, especially for the higher tones, appears to exclude arteriosclerosis in the ears as a cause of the deafness.

The author gave a summary and conclusions and ended his paper with the statement that it appears that audiometric measurements in cases of arteriosclerosis with loss of hearing could be used as an aid in determining the rate of progress of the cardiovascular disease.

DISCUSSION

DR. ROBERT WILSON, Charleston, S. C.: There is some question, I think, as to whether one is justified in assuming that arteriosclerosis may commonly be the determining factor in the loss of hearing of old age because old age is regularly, but not always, accompanied by arteriosclerosis. Also, independent of the presence of arteriosclerosis, it is probable that the capillaries undergo retrogressive changes. This is probably the natural process of growing old. It occurs so gradually that frequently one who is afflicted with deafness does not appreciate its onset and its

progress. The ganglion cells are impaired through lack of sufficient nutrition from the capillaries. As Dr. Fowler says, arteriosclerosis is a "patchy disease," different portions of the arterial system being variously involved. Hence, one organ may be much more involved than another, and the symptoms will thus depend on the organ or organs most affected. My associates and I have depended largely on examination of the eyegrounds, but if Dr. Fowler's investigation proves fruitful we shall have another resource.

Dr. H. M. Taylor, Jacksonville, Fla.: Dr. Fowler emphasizes the importance of changes which may occur in the internal ear as a result of pathologic changes elsewhere in the body. The fact that arteriosclerosis is of a patchy nature explains why in a group of patients suffering from this condition some will have disturbance of the function of the heart, others of the kidneys and others of the ears, eyes, brain, etc. The closest approach to a diffuse generalized arteriosclerosis is found in the blood trunks of the kidneys, while the most characteristic patchiness is in the aorta and coronary vessels and in the cerebral vessels. In studying the effect that severe illness may have on the hearing it is important not to ignore the possibility that drugs administered might be a factor in the production of nerve deafness.

Dr. Hill Hastings, Los Angeles: All otolaryngologists see occasionally cases in which there is sudden severe unilateral deafness. I think that these cases are due to focal infection; the Wassermann reaction is rarely positive. There are also cases of inflammatory lesions of the inner ear, and in these the hearing returns. In cases of herpes of the ear there are no ocular manifestations to help in the diagnosis. Therefore, one should be on the lookout for specimens which may show inflammation of the spiral and Scarpa's ganglions.

Dr. Edmund Prince Fowler, New York: I think that if one will regularly test old people one may learn some interesting things. The sclerosed vessels are usually found in the internal auditory meatus. I also have found very few patients with positive Wassermann reactions. Yet the curve looks like a typical curve of nerve deafness and of syphilitic deafness, because I forgot that a person may have syphilis and not have syphilitic deafness.

Cancer of the Larynx: Observations on Two Hundred Consecutive Cases. Dr. Gabriel Tucker, Philadelphia.

This article will be published in full in a later issue of the Archives.

DISCUSSION

Dr. Chevalier Jackson, Philadelphia: I was glad to hear the matter of biopsy emphasized so strongly. Biopsy on the larynx is without any danger because of the peculiar lymphatic distribution. One deplorable thing is that statistics on laryngofissure are cluttered up with records of cases that do not belong in that category. In cases of lesions involving the anterior commissure the incision should be made only through the cartilage, the dissection then elevating the perichondrium and with it the underlying tumor. One should never cut through the growth. The cartilage and its perichondrium are invaded very late, in fact not until pyogenic infection has paved the way.

The five year cures obtained by my associates and me now amount to 82 per cent. The most appalling fact in cases of laryngeal cancer is that almost all the patients come too late for surgical intervention, even for laryngectomy. We otolaryngologists must educate the laity on this point, and we must examine the anterior commissure more definitely.

Dr. Joseph Beck, Chicago: At the Hines Veterans' Hospital patients are referred to a specialist for irradiation when the condition is still operable. I am not convinced of the wisdom of this, and I still hope for the operation that has been demonstrated here.

Dr. Perry G. Goldsmith, Toronto, Canada: In cases of laryngeal cancer the biopsy should be made by some one who is accustomed to making accurate laryngeal manipulations, and the pathologic examination should be made by a pathologist experienced in the study of laryngeal lesions. The symptom of hoarseness cannot be emphasized too strongly. Medical students should understand this thoroughly. It is dangerous to accept a negative pathologic diagnosis if clinically the case is predominantly malignant. I do not favor the use of radium in the larynx; high voltage roentgen irradiation may be used in extensive, incurable cancer.

Dr. W. B. Chamberlin, Cleveland: I think that the otolaryngologists should educate not only the laity but the medical profession. Does Dr. Tucker remove the block of tissue with a knife or by diathermy?

Dr. T. E. Carmody, Denver: I think that five year cures are important, but some of the cases recur a few years after that period.

I do not think that one should use caustics in the larynx, especially silver nitrate.

The endotherm knife is satisfactory in cases of laryngofissure, but one must know how to use it properly.

Dr. Gabriel Tucker, Philadelphia: I have not used the endotherm knife. I am afraid of the possible effects on the cartilage.

The finding of cancer in the larynx after five years does not necessarily mean that it is a recurrence; it may be a new growth.

The Biplane Fluoroscope in Bronchoscopy. Dr. Murdock Equen, Atlanta, Ga.

In his introduction, the author epitomized the history of removing foreign bodies from the air passages, with particular emphasis on the American pioneers in this field. The use of the biplane fluoroscope in bronchoscopy was introduced in 1915. During the early days some enthusiastic operators used it as a substitute for bronchoscopic skill with disastrous results. Grier, Jackson and Tucker, aided by Manges, Prendergrass and Pancoast, have improved the technic so that it now entails little risk.

The use of the biplane fluoroscope is indicated when a radiopaque object in the tracheobronchial tree is unusual or irregularly shaped, with cutting edges or sharp points, and when the foreign body is beyond direct vision through the bronchoscope, either on account of its actual location or on account of associated inflammatory processes. The removal from the esophagus of open safety pins, large, irregularly shaped objects or objects that have been lodged there a long time or that are associated with strictures or other lesions also requires the fluoroscope.

Two cases were reported in which the biplane fluoroscope was used. In the first, that of a child, aged 6 years, who had had symptoms of pulmonary tuberculosis for nearly two years, a pin was found in the posterior bronchiole of the lower lobe of the left lung. The child made a prompt and uneventful recovery after the removal of the pin. The second case was that of a little girl who had swallowed a bobbin from a textile machine thirty months before. This had lodged in the upper part of the esophagus and had required a gastrostomy. At the time she came under the author's care, scar tissue around the bobbin had occluded the lumen of the esophagus. Under observation with the biplane fluoroscope the bobbin was released by means of sharp dissection and extruded through the stomach. Poverty and ignorance prevented the parents from bringing the child back at frequent intervals for dilatations of the esophagus, but more than a year later she was in good condition and able to swallow almost anything.

DISCUSSION

Dr. Chevalier Jackson, Philadelphia: I heartily endorse all that Dr. Equen has said. The double plane fluoroscope, while exceptionally advantageous for use in certain cases, does not solve all the difficulties. Sometimes the foreign body

may be visible on the x-ray film but not under the fluoroscope. It is important in this work that the proper smaller bronchus be found for the bronchoscope by careful palpation. In the hands of a skilful bronchoscopist such as Dr. Equen, the use of the biplane fluoroscope is safe and is attended with a large percentage of successes. In the hands of one who has never done eye-guided bronchoscopy and who does it guided by the fluoroscopic screen, the mortality is high.

DR. GABRIEL TUCKER, Philadelphia: I wish to emphasize that both the roentgenologist and the trained bronchoscopist are necessary for these cases.

DR. RALPH F. DAVIS, Portland, Ore.: I recently observed an interesting case. A 19 month old boy had a small tack, with the head buried, deep in the left lung. In spite of the use of the fluoroscope my associates and I were unable to remove it until the fourth attempt, and then lower bronchoscopy was used. Recovery was uneventful.

DR. MURDOCK EQUEN, Atlanta, Ga.: One may never use the biplane fluoroscope, or one may need it tomorrow.

MYCOTIC INFECTIONS OF THE MAXILLARY SINUSES. DR. H. N. STEVENSON, Rochelle, N. Y.

This paper was published in full in the September issue of the ARCHIVES, page 340.

DISCUSSION

DR. DUNCAN MACPHERSON, New York: I have observed one case of fungous infection of nasal origin. On looking up the subject, I found that Dr. Stevenson has gathered together about all that is known about the subject. All fungi grow on maltose agar so profusely that differentiation is impossible. From this, however, they may be transplanted to cornmeal agar, on which they grow only sparsely, which permits easier differentiation.

DR. JAMES G. DWYER, New York: My associates and I divide all molds of the lower grade, leaving out Blastomyces and Actinomyces, into three divisions on the basis of their method of growth. A splendid way to recognize Mucor is to grow it near a moist place. Aspergillus, which is obtained time and again, is sexual. Blastomyces, the yeast, is obtained only in jars and around injured bones, not as a primary invader. A mold containing chromatin is an accidental invader and never pathogenic. There is no difficulty about the classification of molds, but it is difficult to determine their pathogenicity.

DR. WILLIAM B. CHAMBERLIN, Cleveland: Molds of the ear are common, but they are not easy to get rid of. I recently observed a case of a mold in the vestibule of the nose. I finally got rid of it by using phenol mercuric nitrate and phenol mercuric chloride. I am also using that combination in cases of atrophic rhinitis and for irrigations of the sinuses. I hope to give a report later.

DR. M. A. LISCHKOFF, Pensacola, Fla.: I wish to report the case of a man, 61 years of age, who had an Aspergillus infection of the nose. A sublabial antrotomy was done, and the fuzzy, white mold could be seen in the curetted membrane. The condition then cleared up.

DR. H. N. STEVENSON, Rochelle, N. Y.: In speaking of chromatin one means the particular part of the cell which picks up the stain. This series of patients were treated principally with metaphen, neosilvol and mercurochrome. I feel that this subject warrants further study.

THE SPHENOID SINUS: POSTOPERATIVE OBSERVATIONS FOLLOWING OPERATIONS ON THE ETHMOSPHENOID SINUSES. FREDERICK T. HILL, M.D., Waterville, Maine.

This paper was published in full in the September issue of the ARCHIVES, page 351.

DISCUSSION

DR. LYMAN G. RICHARDS, Boston: In the execution of surgical procedures on the sphenoid sinus, the operator has one of two main objects in view, dependent on the type of the existing pathologic process: The first is the improvement of drainage in purulent sphenoiditis, and the second is the removal of a diseased lining membrane when such a membrane is felt to be acting as an allergic irritant. The second procedure, I find, necessitates the external approach. Even with this, it may not be successful in certain cases. Perhaps one must always be prepared to encounter individual tissue reactions just as in the case of the maxillary antrum. As in all surgical work, there lies a happy medium between conservatism and radicalism which must ever be the object of one's quest.

DR. HAROLD G. TOBEY, Boston: Again one is between the conservative and the radical approach. I agree with Dr. Hill that in allergic cases when the sphenoid sinus does become blocked up there is a return of the symptoms. Of course, all otolaryngologists realize that operation is often necessary in the allergic cases. In many of them the sphenoid sinus does close up, but there are no further symptoms. The question, then, is: Is it always necessary to keep the sinus open?

DR. FRANK KISTNER, Portland, Ore.: I also have had trouble as a result of closing of the opening of the sphenoid sinus, but it is possible to make a graft from the mucous membrane covering the anterior portion of the sphenoid sinus. In the ideal operation, the lining membrane of the sinus is removed entirely. I think that this can be done in over 80 per cent of the cases. Then there is the probability of complete, or almost complete, obliteration of the sphenoid sinus with granulation tissue. The closing of the opening in allergic cases may be due only to a temporary allergic edema.

DR. HENRY ROSENBERGER, Cleveland: I have recently filled the sphenoid sinuses of 50 cadavers with barium sulphate paste and had them examined roentgenologically. I was very much surprised at the tremendous size of the sinus. From this study I think that the opening closes when the anterior wall is thick. The extreme thinness of the walls adjacent to the optic nerve and trigeminus nerve in many cases would make curettement dangerous.

DR. FREDERICK T. HILL, Waterville, Maine: The details of technic were left out of the paper. I think that in allergic cases the lining of the sphenoid sinus should be removed; hence, the external approach is used. Diathermy has been unsatisfactory. An internist worked with me on all these cases.

A CLINICAL ANALYSIS OF FIFTY CASES OF CHRONIC SUPPURATIVE OTITIS MEDIA WITH CHOLESTEATOMA. DR. KENNETH M. DAY, Pittsburgh.

Moisture is the primary and major factor in the development of cholesteatoma. Only anhydrous solutions should be employed in the presence of cholesteatoma. Conservative treatment should be tried only in the absence of symptoms or signs of extension beyond the confines of the middle ear and mastoid. A cure can be obtained only if there is complete epidermization of the walls of the cavities. The presence of moisture will prevent cure and cause recurrences. This is especially true if granulations or an open eustachian tube is present.

Conservative treatment is rarely successful in young children because of tubal secretion. Periodic examinations are important after the ear has become dry. The early recognition and proper treatment of chronic otitic suppuration with cholesteatoma should obviate the need of radical operation and prevent the serious complications which so commonly occur at present.

The author reported a total number of 50 cases. In 14 of these he performed a radical operation on the mastoid. In 10 of the 14 there was extension of the infection to the dura or labyrinth. In 37 cases conservative treatment was used, with a dry ear resulting in 31, or 84 per cent. The conservative treatment consisted of: (*a*) providing free drainage, as by removing polyps or granulations, (*b*) removing the cholesteatoma by lavage, using only 95 per cent alcohol or ether, followed by suction, and (*c*) having the patient use drops of 95 per cent alcohol at home.

DISCUSSION

DR. SAMUEL J. KOPETZKY, New York: This is a most provocative paper, and in the main I agree with the formulative conclusions that the essayist presents. Moisture is a factor, but not the prime factor. The cholesteatoma is a thwarted effort of nature to heal a chronically suppurating ear. Squamous epithelium comes in to form a scar, but because of osteoblastic action by pressure of the foreign body against the bone irregularity occurs; then as it ingrows, it turns on itself. Therefore, the bone irregularity is a prime factor.

Children give poorer results because nature has not yet progressed a considerable stage toward cure.

From my experience and observation, I believe that all patients with cholesteatoma should be operated on. I also contend that one can dissolve carbon tetrachloride with alcohol and can dissolve the detritus, and by keeping the patient under continuous observation one can clean out the collections of detritus. But if one does not smooth out these areas the patient is always a potential subject for an epithelization that gradually forms. In the radical operation I even use a magnifying lens to see that the tissue is absolutely smooth so that there will never be any chance for the healing cholesteatoma matrix scar to turn.

DR. JOSEPH C. BECK, Chicago: This is the first paper in English since Wittmaack's publication on pneumatization and cholesteatoma formation to show how cholesteatoma reforms. I feel definitely that moisture is the greatest factor in epithelial desquamation. The mechanical treatment outlined has some possibilities of complications unless carried out by such an expert as Dr. Day. I believe that hidden cholesteatoma should be operated on, even in children. However, I do not agree that a matrix is a healthy condition. I like to remove the cholesteatomatous matrix. Smoothness of the cavity is, of course, an important factor. Lastly, associated bone necrosis must also be removed.

DR. HILL HASTINGS, Los Angeles: I think that one should not lean too much one way or the other; one should try to keep to a happy medium.

DR. EWING W. DAY, Pittsburgh: I have found many cases in which the patient could be successfully treated without operation. There are very few surgeons in this country who can do a really good and successful radical operation. I think that the patients whom I have treated conservatively are as safe as they would have been after the average operation.

DR. W. W. PEARSON, Des Moines, Iowa: I have always been conservative in my practice. In regard to the fistula test, I have observed a patient with a dry ear over a number of years, and he has never been operated on. I have used the Zeist telescopic lens for years in the examination of mastoid cavities.

DR. JAMES G. DWYER, New York: I congratulate Dr. Day on his conservative, common-sense paper. There are certain patients that must always be operated on, but the presence of cholesteatoma in itself does not require radical operation on the mastoid.

DR. EDMUND PRINCE FOWLER, New York: I wish to back up what Dr. Dwyer has said. I do not think that one obtains very good hearing after a radical operation. This is especially true in children.

DR. GEORGE L. TOBEY, Boston: It is important to emphasize the use of anhydrous solutions. In clinic work I advise the radical operation; in private practice, I agree somewhat with Dr. Day.

DR. VERNON L. BISHOP, Rochester, N. Y.: Why is moisture the primary factor?

DR. KENNETH M. DAY, Pittsburgh: Lack of moisture implies lack of infection. Patients with rough places in the bone do not get well, and one has to operate. The significance of moisture has been known for years, but I have not seen it specified in black and white in the literature that it is a primary factor in the *formation* of cholesteatoma.

CYSTS AND RETENTION ABSCESSES OF THE NASOPHARYNX (CANDIDATE'S THESIS). DR. BARNEY M. KULLY, Omaha.

The author reported 88 cases, occurring mainly from 1880 to 1900. The majority of the patients were between the ages of 18 and 35. Twenty-five per cent were free from symptoms. In the diagnosis, direct inspection is necessary. Examination with a postnasal mirror and a nasopharyngoscope is inadequate.

DISCUSSION

DR. JOHN B. POTTS, Omaha: I do not think that a paper on this subject which was as detailed as this one has ever been presented before the society. It is my opinion that these cysts are sufficiently frequent that the routine use of Kelley's direct vision adenotome or of Yankauer's speculum should be insisted on in all cases in which there is a suspicion of focal infection. The only satisfactory way of dealing with these cysts is to remove the anterior wall with a biting forceps. If a patient has a headache, postnasal discharge or postnasal scab with constant irritation, or bad breath, and a cyst of this kind is found and taken care of, the symptoms are usually relieved.

DR. JOSEPH C. BECK, Chicago: A radiopaque substance may be injected into these cysts to show the extent of the cavity. Goerke has devised an excellent instrument for operating on these cysts. Electrothermic destruction of the lining membrane is successful and should be mentioned.

DR. FRANCIS B. BLACKBORE, Columbus, Ga.: I wish to demonstrate an instrument for this purpose which Dr. Lynch used.

DR. LYMAN G. RICHARDS, Boston: I do not think that congenital cysts in the lateral pharyngeal pouch are ever located in the midline.

DR. BARNEY M. KULLY, Omaha: I wish to emphasize that these cysts are more frequent than has been believed.

COLLEGE OF PHYSICIANS, PHILADELPHIA, SECTION ON OTOLARYNGOLOGY

WILLIAM S. HEWSON, M.D., *Secretary*

March 21, 1934

A CASE OF CHLORINE GAS POISONING. DR. PHILIP STOUT.

This case was due to inhaling the gas from a bottle which was jokingly poked into the patient's mouth. Burns resulted on the inside of the right cheek, right anterior and posterior faucial pillars, soft palate, posterior pharyngeal wall, larynx, trachea and bronchi. The patient felt sick, giddy and weak at once, and soon headache developed. Several hours later he had a great deal of pain in the throat, which interfered with sleep and swallowing. Recovery occurred, with some impairment in general health and strength and partial aphonia.

THE SPHENOID SINUS. DR. ROBERT F. RIDPATH.

The sphenoid sinus arises from the cartilaginous nasal capsule. According to Shaeffer it is demonstrable as early as the fourth month of fetal life, and no portion of it is contained within the sphenoid bone. Until the third year of life the sinus is nasal in position, while in the adult it is directly in the body of the sphenoid bone and occupies almost a central position in the skull. Pneumatization is exceedingly variable, frequently extending into the pterygoid processes, the lesser wings of the bone and the anterior clinoid processes. Seldom does one see complete nondevelopment of the sphenoid sinus.

The ostium situated in the upper third of the anterior wall is visible only when near the median line, and with a normal spheno-ethmoid fissure visualization of the opening is impossible. Closely associated with the superior wall are the right and

left optic nerves and the optic chiasm. Above and slightly posterior are the coronary sinuses and the pituitary body in the sella turcica. Within the mucous membrane covering the antero-inferior wall is the pharyngopalatine artery, which when cut causes a frightful hemorrhage. The external wall helps to form a portion of the middle cerebral fossa and is in apposition with the cavernous sinus and the internal carotid artery. Numerous perforations are present for the passage of small venous capillaries which anastomose with the cavernous sinus.

When diseased, the sphenoid sinus gives rise to a complexity of symptoms. Those associated with acute infection are pain, inability to concentrate, aversion to mental or any work, cough, malaise, anorexia and vertigo. Objectively there are discharge, cacosmia, crusts or pus on the pharyngeal wall and more or less proptosis of the eye. The ocular symptoms which may be present are enlargement of the blind spot and scotoma.

The diagnosis of disease of the sphenoid sinus cannot always be made by the routine examination. When a condition is present which might be caused by infection of this sinus it is justifiable to pause and examine the sinus carefully, even when the nose is otherwise normal.

The making of a satisfactory examination requires, first, inspection of all parts of the nose. Next shrinking of the mucosa with a weak cocaine solution, requiring about ten minutes, is necessary. A second examination is then made, touching up with a stronger cocaine solution various areas which did not respond before. A careful postrhinoscopic examination should be made, as well as examination of the mouth, tonsillar areas and larynx.

When one uses the pharyngoscope and the Skillern probe to find the ostium, there will frequently be seen a bead of white pus draining from the sinus along the shaft of the probe. There may be heard a noisy inrush of air into the cavity when an anaerobic infection is present. It is doubtful if one ever sees an acute sphenoid infection, without other choanal inflammation.

Taking up the symptoms of acute empyema of the sphenoid sinus, pain may be due to pressure or to reflex or toxic manifestations. Headache depends largely on pressure or vacuum. The latter may be due to swollen tissue or polypi occluding the ostium of the sphenoid sinus from outside. The headache is mainly situated in the occipital region, radiating toward the vertex.

Reflex pain is accompanied frequently by muscular stiffness in the neck. Reflex pain is also felt sometimes over the canine tooth of the side affected or at the junction of the soft palate with the anterior pillar of the faucial tonsil. Another type is a dull, sickening pain felt over the pyriform crest. Still another type is lancinating pain over the instep. Pain back of the eye is dull and not increased by pressure over the eyeball.

Vertigo may be present either in the recumbent or in the upright position. A peculiarity of gait is noticeable in some cases. Sleeplessness may result from a feeling of something breaking into the throat periodically, when a certain amount of pus is discharged. Cough is a most persistent symptom and is accompanied by a sensation of tickling. Malaise and forgetfulness, with inability to concentrate, are usually present.

No other sinus presents such a wide deviation in symptoms as the chronically diseased sphenoid sinus. The objective symptoms which may be observed are: congested postethmoidal mucous membrane and swollen tissue in the sphenoethmoid fissure with possibly a discharge in the olfactory fissure and on the pharyngeal wall; a tenacious dark yellow or greenish discharge clinging to the pharyngeal wall; a typical cacosmic odor; enlargement of the blind spot, and paralysis of the external ocular muscles. The subjective symptoms may be divided into: pressure symptoms, mental symptoms, ocular symptoms, toxic symptoms, olfactory symptoms and general systemic symptoms and complications, such as thrombosis of the cavernous sinus, retrobulbar neuritis and basilar. meningitis.

DISCUSSION

DR. SAMUEL R. SKILLERN JR: I want to emphasize the relation of the third nerve to the outer wall of the sphenoid sinus. This nerve, among other things,

controls the upper eyelid. In one case at operation on this sinus a spicule of bone was removed from the lateral wall, exposing the third nerve. Eyelid drop promptly developed. I am glad that Dr. Ridpath mentioned swelling of the mucous membrane in the spheno-ethmoid recess as a sign of disease of the sphenoid sinus.

DR. OSCAR V. BATSON: The ethmoid labyrinth commonly abuts on the anterior wall of the sphenoid sinus, and the spheno-ethmoid fissure rarely completely separates it from the sphenoid sinus.

TUBERCULOSIS OF THE LARYNX. DR. ROBERT M. LUKENS.

The larynx is influenced by infection of the upper respiratory tract and by trauma due to cough and vocal abuse.

Laryngeal lesions do not follow the course of the pulmonary lesion necessarily. Tuberculosis of the larynx may improve under proper treatment, while the pulmonary lesion becomes worse. Consequently, a tuberculous patient should be under the care of both an internist and a laryngologist at all times.

Routine examination of the nose and throat of tuberculous patients reveals that the vast majority suffer from nasal and pharyngeal infection and many from advanced sinus disease. In any case of tuberculosis of the larynx in which there is the least suspicion of cancer, a biopsy should be made. Cautery is accepted as a curative treatment for laryngeal tuberculosis. However, in the hands of the inexperienced, cautery can be dangerous. In doubtful cases it is well to make only one cautery application and watch the reaction of the tissues as a guide. Frequent gentle treatment is far better than vigorous extensive treatment at longer intervals.

The only indications for tracheotomy are uncontrollable vocal abuse and an emergency.

To be effective, chaulmoogra oil must be the true chaulmoogra oil, an organic oil, which as such is absorbed by the tissues. If used carelessly or unskilfully some of it may be swallowed and produce gastritis. It has no effect on pyogenic infections of the larynx but acts as a bactericide for acid-fast bacilli.

In advanced and extensive involvement of the larynx, injections of alcohol around the superior laryngeal nerve relieve painful swallowing for from one to eighty days.

DISCUSSION

DR. LOUIS H. CLERF: I enjoyed Dr. Lukens' paper and envy him his results in treating tuberculosis of the larynx. I should like to emphasize the importance of doing biopsies on the larynx.

DR. JAMES A. BABBITT: I commend a man who has been so honest about his methods and so willing to cast aside many of the former procedures which were found wanting. What are the indications for the use of *p*-chlorophenol?

DR. GABRIEL TUCKER: I too enjoyed Dr. Lukens' presentation, and like Dr. Clerf I am interested in his remarks about biopsies. I also have not seen any ill effects from this procedure.

DR. E. J. DONNELLY: In some cases cautery produces a severe reaction. What does Dr. Lukens consider as the indications for its use?

DR. ROBERT M. LUKENS: Answering Dr. Babbitt's question, *p*-chlorophenol is used mainly in subacute, chronic or irritated conditions of the larynx. There is only one reason for the use of cautery, and that is to reduce greatly swollen and edematous arytenoids. It makes no difference whether the patient has fever or not, but it is important to note whether the larynx looks as if it would stand cautery puncture well.

THE PEDICLE OF THE TONSIL (CHALK TALK AND DEMONSTRATION WITH WET SPECIMEN). DR. OSCAR V. BATSON.

Coursing posterolaterally from the tonsil and oropharynx into the deep tissues of the neck, there is on each side a pedicle-like structure which separates the

retropharyngeal space from the pharyngomaxillary space of the same side. This pedicle contains the styloid muscles, the carotid arteries, the internal jugular vein and the associated dense connective tissues. These make a firm, dense mass the intricate anatomic structure of which need not be disturbed in the surgical drainage of suppurative collections in the retropharyngeal or pharyngomaxillary space. Either space may be entered by an incision in the skin and fascia at the places where the space approaches nearest to the surface.

An incision parallel to and in front of the sternocleidomastoid muscle at the level of the angle of the jaw allows blunt dissection forward and upward along the internal pterygoid muscle. This exposes the entire pharyngomaxillary space, and since the pedicle lies behind, the procedure is practically bloodless.

An incision parallel to and behind the sternocleidomastoid muscle, in the lower half of the neck, permits a blunt dissection to be carried into the retropharyngeal space behind the great vessels and the viscera of the neck, for here the pedicle lies in front. It is possible here, in what amounts to a bloodless manner, to ascend in the retropharyngeal space to the base of the skull or to descend into the mediastinum.

As demonstrated in the anatomic specimen, with one index finger through the upper incision and the other index finger carried upward through the lower incision, the pedicle of the oropharynx and tonsil, terminating in the tonsil, lies between the fingers.

DISCUSSION

DR. BENJAMIN SHUSTER: From the clinician's standpoint, many of the questions brought out by Dr. Batson are not of practical importance. Injection into the peritonsillar space from the neck for an operation on the tonsils seems unnecessarily dangerous, and the practical approach to a pharyngeal abscess seems to be through the mouth. From the standpoint of locating the spread of infection, this demonstration is important and interesting. On the other hand, it is not so simple to manipulate the tissues in a living person as in a specimen. Dr. Batson's incision at the angle of the jaw has the danger of injury to the facial nerve. The incision of Dr. Mosier is simpler and allows one to reach the tissues beneath the floor of the mouth without danger.

DR. ROBERT M. WOLFF: Might one open a pharyngeal abscess through Dr. Batson's incision?

DR. SAMUEL R. SKILLERN JR.: I recall four or five cases in which there was brawny swelling in what I think is the prevertebral space as a result of disease of the maxillary sinus.

DR. OSCAR V. BATSON: I thank Dr. Shuster for his balance-wheel discussion. On account of adherence at the median raphe of the fibrous tunics, a peritonsillar or pharyngeal abscess will not pass the middle line, but once in the retropharyngeal space it will spread to both sides. The point about danger to the facial nerve is well taken; incision must be low enough to obviate this danger. As to Dr. Skillern's observation, I think that such swelling is due to lymphatic drainage to the prevertebral region.

Regular Meeting, April 18, 1934

BENJAMIN D. PARISH, M.D., *Chairman*

KARL M. HOUSER, M.D., *Clerk*

THE INFLUENCE OF ALLERGY ON RHINOLOGY. DR. W. V. MULLIN.

Allergy is a subject that should receive increasing attention from rhinologists. The failure to recognize and evaluate the importance of allergy in many cases seems one of the outstanding causes for the failure of operations on the nose and sinuses.

I agree with Kern and Schenck of Philadelphia that allergy is the cause of the mucous polyp. I disagree slightly with Grove and Cooke of New York in that I believe that a primary bacterial infection in a sensitized membrane is not always necessary for the formation of the mucous polyp. The difference between hyperplastic tissue and the true mucous polyp is minimal, and it is unimportant whether the infection precedes, is secondary to or is concomitant with the allergic disturbance.

Fox and Fabricant of Chicago stress the nonallergic factor in cases which they designate as "hyperesthetic rhinitis." Their stress on the importance of operations to eradicate infection and to increase ventilation seems erroneous. In attempting to rid the sensitized nose of all infection, they overlook the fact that acute infections lower the threshold of sensitivity to allergens. They apparently ignore physical allergy entirely when they state that some of their patients' symptoms are made worse by heat and cold.

Sewall believes that sinusitis is always more than an allergic condition and that if allergy is a predisposing cause of the sinusitis, it is such only through interference with drainage from the sinus. He admits, however, that relief of allergic swelling may so improve the drainage that the sinusitis clears up.

The fact that bacteria are obtained from surface cultures, from sinus washings and even from the tissues, as Grove and Cooke and others have shown, does not disprove the prime importance of the allergic factor. The evidence for its importance is much more striking and convincing. An attack on the infection will not relieve the nasal edema or prevent recurrence of the mucous polyp, but complete desensitization in early cases will rid the patient of both the edema and the infection. Furthermore, I have observed cases in which autogenous vaccines prepared from nasal cultures produced neither local nor general reactions, and yet all the infection was eliminated by eradication of the offending allergens.

The average rhinologist has neither the time nor the training and experience necessary to make complete studies of allergy in his patients. The patient wants symptomatic treatment that will give immediate relief and does not want to be bothered with the inconvenience of seeing another physician. The situation has to be carefully explained to him in order to get him to take this step and to cooperate.

The success of the method is in direct proportion to the thoroughness of the study and the time devoted to explaining the problem to the patient. Cooperation from the patient is seldom secured at first, and usually lack of progress and relapses are necessary to convince him that half-way measures are futile. There is a decided advantage in giving the patient written instructions.

To elicit a complete history in these cases necessitates considerable training and experience, and often the diagnosis can be made from the history alone.

After a complete history has been obtained, a comprehensive study of the allergy is necessary. Tests for a few allergens, undertaken haphazardly, will not tell the true story and may deceive the examiner entirely. The patient should be tested with all possible offending substances. A recheck in from sixteen to twenty-four hours is made to detect delayed reactions. Some of my best therapeutic results have followed the elimination of allergens in patients who exhibited questionable reactions to the tests.

The treatment depends on the requirements of the individual patient, and the results depend on the adequacy of the investigation, the patient's comprehension of his own problem and his following of specific instructions regarding the elimination of offending allergens. The only diet indicated in these cases is one in which the foods to which the patient is sensitive are eliminated.

The child with allergic disease has marked demineralization of the bones. The administration of cod liver oil, viosterol, calcium, potassium or phosphates has no effect until the allergic condition is under control. Todd suggests that the lining membrane of the intestinal tract is impervious to minerals until the irritating foods or inhalants are omitted.

Most cases of hypersensitivity in allergic patients are made worse by local treatment. When shrinking preparations, such as epinephrine and ephedrine, are used extensively, vasomotor paralysis is soon produced, and then local applications become irritating. As for surgical treatment in this type of case, there is ample proof that operation on the nose or sinus without correction of the allergic disturbance will not relieve the symptoms and that it will make the patient more miserable.

Case 1 illustrates that an incomplete study of allergy and operation performed before adequate control of the allergic factor is accomplished conspire to produce a most unsatisfactory result.

Case 2 shows that an edematous mucous membrane over a slight deviation or hypertrophy may magnify the necessity for an operation. If the allergic condition is controlled adequately, surgical intervention is unnecessary.

In case 3 the severe symptoms of disease of the sinus were almost entirely corrected with allergic control, so that only a minor surgical operation was necessary.

Case 4 illustrates the significance of questionable reactions and shows that the cooperation of the patient is of the utmost importance in securing satisfactory results.

Case 5 emphasizes that in cases of hay fever it is not sufficient to test for pollens only, for the patients are nearly always sensitive to other allergens as well, and a good result from treatment of the hay fever will not follow unless the other irritants also are eliminated.

Case 6 illustrates that the allergic factor can be of extreme importance even in the most severe purulent sinusitis, and that elimination of allergens in such instances accomplishes more than multiple radical operation.

These clinical cases emphasize that satisfactory results in the treatment of diseases of the nose and sinuses cannot be obtained without adequate knowledge and proper evaluation of the allergic factor.

UNDERLYING PRINCIPLES OF ALLERGY. DR. JOHN KOLMER.

From 5 to 10 per cent of human beings present clinical manifestations of allergy, while a larger number give positive skin reactions without clinical manifestations. Among the better known allergic diseases may be mentioned: hay fever, vasomotor rhinitis, vernal conjunctivitis, asthma, eczema, urticaria, angioneurotic edema, erythema multiforme, acute gastro-intestinal allergy, drug allergies, serum allergies and biologic allergies.

A large number of new terms have been proposed from time to time. The first was anaphylaxis, proposed by Richet and meaning "without protection," but the best and most widely used is allergy, coined by von Pirquet and meaning "altered reactivity."

The exciting agent is generally designated as allergen, atopen or anaphylactogen. The antibody concerned is called allergin, reagin or anaphylactin. The exciting agents of allergic sensitization are usually proteins or protein derivatives. Pure protein-free fats do not produce sensitization. Complex carbohydrates and especially carbohydrate-protein *moitiés* may be allergens, such as pollens, plants, etc. Drugs, including the metals, may be allergens, presumably by combination with body proteins to form protein complexes sufficiently foreign to excite sensitization. Bacterial products, including toxins, are probably proteins or protein-carbohydrate combinations. Theoretically, human beings may acquire allergic sensitization to any foreign protein of animal or vegetable origin, especially to those to which they are predisposed by heredity. Consequently the list of known allergens is bewilderingly large and is growing every year. These agents gain access to the body by inhalation, by ingestion, by contact with the skin and by injection.

An antibody to the exciting agent or allergen is necessary for the production of allergy. It is called allergin, reagin or anaphylactin. When it is in or on cells the cells are said to be "sensitized." The antibody may be free in the blood serum

and has been found in serum allergy, hay fever, asthma and eczema. It has not been demonstrated in urticaria, angioneurotic edema, migraine or drug allergies. The amount of antibody present in the blood is proportional to the degree of skin reactions but not to the severity of the symptoms.

The most commonly accepted theory of the mechanism of allergy is the "cellular theory." The exciting agent or allergen engenders antibody. The antibody occurs principally in or on cells; subsequently, when the allergen gains access, it unites with the antibody. The result is allergic shock of the cell, producing or liberating a histamine-like substance responsible for the lesions and symptoms. The union of a free or circulating antibody in the blood with an allergen is believed to be without harmful effects and may prevent shock of cells.

Heredity exerts an important influence on allergy. The nature of this is not known; it is apparently a dominant mendelian character, probably an exaggerated capacity of body cells for acquiring sensitization along with an unstable or hyperexcitable vasomotor system. Women are more likely to transmit the hereditary factor than men. Sensitization requires contact with the exciting substance or allergen, but contact alone does not result in sensitization in the absence of the hereditary factor. There is a tendency to specificity in the hereditary factor.

Desensitization means the removal of antibody from sensitized cells. This is usually accomplished by the gradual administration of an extract of allergen and forms the basis of specific therapy. Partial desensitization may sometimes be accomplished by the administration of unrelated substances, such as peptone, sodium chloride, etc.

In the diagnosis of allergy a detailed and careful investigation of the history and physical examination are of great importance. Skin tests are invaluable but can err. Scratch tests are usually sufficient. Intracutaneous tests are more sensitive but more likely to yield nonspecific reactions. Tests of the eyes and nose are sometimes serviceable. Patch tests are sometimes required. The method of passive transfer to susceptible skins is occasionally useful. The therapeutic test or trial method may be necessary.

In the treatment of allergy, there is no short cut or royal road to specific desensitization. A large number of injections or administrations of the exciting agent are required over a long period. Epinephrine hydrochloride and, to a lesser extent, ephedrine are physiologic antidotes for allergic reactions. The treatment of many of the allergies is still unsatisfactory because of the incomplete knowledge of the subject and inadequate methods.

DISCUSSION

DR. J. ALEXANDER CLARK: No allergist would object to anything in either of these papers. The rôle of bacteria in allergy is a large subject. Dr. Cook believes that there is such a condition as bacterial allergy. The effect of bacteria is allergic, and their products should be considered as allergens. The allergist and the otolaryngologist should be closely associated, for otherwise there will be conflict as to what should be done in a given case. I believe that the allergist should know more about otolaryngologic conditions and the otolaryngologist more about allergy.

Frequently the otolaryngologist will tell his patient that the allergist will cure his allergic condition. This is not correct. The allergist hyposensitizes the patient but, correctly speaking, does not desensitize him. The whole condition is predicated by heredity, and one cannot change this any more than one can change the color of the hair. It is possible, however, to reduce the sensitivity.

Estimation of the eosinophils is important in these conditions but in about one third of the cases does not show any relationship to the allergy.

On studying these cases with the roentgen rays one is surprised at the findings in the lungs. All of the patients with asthma in the hospital are examined in this way, and in winter a roentgen examination is made of the sinuses as well. The lungs invariably show the same roentgen picture, whether pulmonary symptoms or nasal symptoms or both are present.

The allergic patient is peculiar also in regard to blood pressure. The pressure is usually low, but raising it does not seem to benefit the patient. Pregnancy may improve the condition or make it worse.

The results of bacterial treatment of allergy are sometimes startling. This is especially true of nasal allergy, which is the type of which the allergist sees too little and the otolaryngologist too much. Among the patients with blocked noses about one-third give no skin reactions. One has to depend on vaccine in these cases, and in some the most dramatic results are obtained with the use of stock vaccine. My associates and I usually start with a 0.1 cc. dose. We had a woman in the hospital today who showed a severe general reaction, urticaria and croup, and tracheotomy seemed almost necessary after a 0.1 cc. dose of Von Cott's vaccine.

Dr. Mullin mentioned the elimination of the allergen in these cases, but this is often the hardest thing to accomplish. He seems to hold a red flag in front of the allergist in advising that the allergist always be consulted and that not much local treatment be given. We allergists have no crows to pick with our otolaryngologist friends, but we should agree with Dr. Mullin in this respect.

Dr. Richard A. Kern: If Dr. Mullin and Dr. Kolmer left anything unsaid, Dr. Clark said it. Dr. Mullin mentioned the meeting in 1912 in this building when some of these conditions were first reported, and Dr. Meltzer reported the case of G. Pig who died of asthma. Sloss reported a case of horse asthma and egg asthma in a child. I wager that at that meeting there was no mention of allergy. The meeting today is devoted entirely to the subject, and there are a journal, clinics and a number of enterprises devoted to allergic conditions.

Dr. Kolmer has painted a picture of what has been learned in the past twenty odd years. To emphasize these points: From 5 to 10 per cent of all persons have at some time in their lives some hypersensitiveness. The mode of expression varies. Look at the formidable list of sensitizing agents! The pendulum is swinging toward allergy, and clinicians are beginning to blame all kinds of conditions on allergy. Physicians are becoming conscious that various disease processes are colored by allergic factors. It is true that persons with these diseases are sensitizable, not necessarily having been born so but having become so.

The allergic child should not overeat of one form of food. A nasal operation or even tonsillectomy should not be performed on such a child in the pollen season. If this is done some subsensitive threshold may be brought to the surface and the patient show some new sensitivity.

A complete diagnosis is essential, and an effort should be made to find all the substances to which the patient is susceptible. Skin tests are not infallible, and therefore it is not to be wondered at that the first session is not always successful. Tests must be repeated, or incomplete treatment will result. It is axiomatic that avoidance of substance to which the patient is sensitive is the best treatment.

Dr. George M. Coates: I have nothing to add to the subject, but I want to express appreciation to Dr. Mullin and Dr. Kolmer for their excellent papers. One is often at sea in determining the underlying factor of allergic symptoms. In this connection, Dr. Arthur Proetz astounded me, a number of years ago, by telling of a case in which the patient's nose was full of polyps and yet when he was examined before operation the next day he showed disappearance of every one.

The newer conception of allergy and of its relation to sinus disease is making otolaryngologists not surgical nihilists but merely conservative in relation to the allergic patient.

Dr. Samuel R. Skillern: All physicians know of the hypersensitivity of some persons' nasal mucous membranes to pollens, dandruffs, dusts, etc., and of the acute swelling with nasal occlusion and possibly bronchial asthma. But is it the nasal membranes that are sensitized? The ingestion of certain foods in another group will give almost similar symptoms. I believe that the sympathetic nervous system is involved and that the local manifestations are simply the weak links in the chain.

The vast majority of these patients show some manifestations of sinus infection. If the sinus infection is the causative factor, are the pollens, dusts, foods, etc., simply the stimulants to the infection needed to cause an overwhelming toxemia, or does the irritation to the tissues lower the patient's resistance to the organisms present in the sinuses?

I have observed two cases of special interest. The first was that of my daughter. At the age of 5 years, following a cold, she contracted purulent ethmoiditis, and both maxillary sinuses became infected. During the winter of her seventh year she contracted bronchial asthma, although there was no history of allergy in her ancestry. At the seashore, an attack would occur during a northeast storm. All skin tests, repeated twice, were negative. Last summer, in the Pocono Mountain region, she was free from symptoms. Biweekly electrotherapeutic treatments continued with local treatments have improved the sinus infection.

The second case was that of a man aged 60 who had progressive asthmatic attacks, necessitating hypodermic injections of epinephrine. Intranasal ethmoidectomy and sphenoidotomy increased his symptoms. Radical opening of the frontal sinuses gave some improvement, and radical opening of the maxillary sinuses gave progressive improvement. He responded to skin tests with numerous foods, pollens and bacterial proteins.

The members owe a vote of thanks to Dr. Mullin and the discussers, Drs. Kolmer and Clark, for their able presentation.

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